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A NOVEL TECHNIQUE FOR SCHEDULING OF FLEXIBLE MANUFACTURING SYSTEM BY USING GA AND TAGUCHI PHILOSOPHY

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ABSTRACT: Scheduling in an FMS environment is more complex and difficult than in a conventional manufacturing environment. Therefore, determining an optimal schedule and controlling an FMS is considered a difficult task. To achieve high performance for an FMS is, a good scheduling system should make a right decision at a right time according to system conditions. Flexible manufacturing system (FMS) scheduling problems become extremely complex when it comes to accommodate frequent variations in the part designs of incoming jobs. This research focuses on scheduling of variety of incoming jobs into the system efficiently and maximizing system utilization and throughput of system where machines are equipped with different tools and tool magazines but multiple machines can be assigned to single operation. Jobs have been scheduled according to shortest processing time (SPT) rule. Shortest processing time (SPT) scheduling rule is simple, fast, and generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in-process inventories (less shop congestion) and downstream idle time (higher resource utilization). Simulation is better than experiment with the real world system because the system as yet does not exist and experimentation with the system is expensive, too time consuming, too dangerous. In this research, Taguchi philosophy and genetic algorithm have been used for optimization. Genetic algorithm (GA) approach is one of the most efficient algorithms that aim at converging and giving optimal solution in a shorter time. Therefore, in this work, a suitable fitness function is designed to generate optimum values of factors affecting FMS objectives (maximization of system utilization and maximization of throughput of the system by Genetic Algorithm approach).

Key Word: GA, SPT, FMS, Taguchi philosophy, simulation modeling and optimization of FMS

I. INTRODUCTION

In today's competitive global market, manufacturers have to modify their operations to ensure a better and faster response to needs of customers. The primary goal of any manufacturing industry is to achieve a high level of productivity and flexibility which can only be done in a computer integrated manufacturing environment. A flexible manufacturing system (FMS) is an integrated computer-controlled configuration in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. FMS consists of three main systems. The work machines which are often automated CNC machines are connected by a material handling system(MHS) to optimize parts flow and the central control computer which controls material movements and machine flow. An FMS is modeled as a collection of workstations and automated guided vehicles (AGV). It is designed to increase system utilization and throughput of system and for reducing average work in process inventories and many factors affects both system utilization and throughput of system in this research system utilization and throughput of system
Has been optimized considering factors.

1.2. Flexible manufacturing system

A system that consists of numerous programmable machine tools connected by an automated material handling system and can produce an enormous variety of items. A FMS is large, complex, and expensive manufacturing in which Computers run all the machines that complete the process so that many industries cannot afford traditional FMS hence the trend is towards smaller versions call flexible manufacturing cells. Today two or more CNC machines are considered a Flexible Manufacturing Cell (FMC), and two or more cells are considered a Flexible Manufacturing System (FMS) "Flexible manufacturing system is a computer controlled manufacturing system, in which numerically controlled machines are interconnected by a material handling system and a master computer controls both NC machines and material handling system."[1] The primary goal of any manufacturing industry is to achieve a high level of throughput, flexibility and system utilization. System utilization computed as a percentage of the available hours (Number of the machines available for production multiplied by the number of working hours), it can be increased by changing in plant layout, by reducing transfer time between two stations and throughput, defined as the number of parts produced by the last machine of a manufacturing system over a given period of time. If the no of parts increases throughput also increases and also system utilization increases. Flexible manufacturing system consist following components

1.3 Work station: work station consist computer numerical controlled machines that perform various operations on group of parts. FMS also includes other work station like inspection stations, assembly works and sheet metal presses.

1.4 Automated Material Handling and Storage system: Work parts and subassembly parts between the processing stations are transferred by various automated material handling systems. Many automated material handling devices are used in flexible manufacturing system like automated guided vehicle, conveyors, etc. there are two types of material handling system.

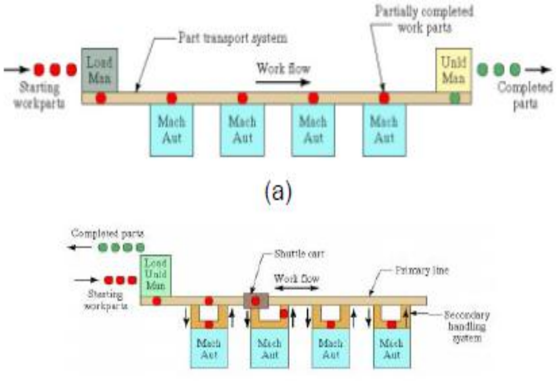
- Primary handling system - establishes the basic layout of the FMS and is responsible for moving work parts between stations in the system.
- Secondary handling system - consists of transfer devices, automatic pallet changers, and similar mechanisms located at the workstations in the FMS.
- Computer Control System: It is used to control the activities of the processing stations and the material handling system in the FMS.

1.3. Flexible manufacturing system layouts

Flexible manufacturing system has different layouts according to arrangement of machine and flow of parts. According to part flow and arrangement of machine, layout of flexible manufacturing system is discussed below.

1.3.1. In-line FMS layout

The machines and handling system are arranged in a straight line. In Figure 1.1(a) parts progress from one workstation to the next in a well-defined sequence with work always moves in one direction and with no back-flow. Similar operation to a transfer line except the system holds a greater variety of parts. Routing flexibility can be increased by installing a linear transfer system with bi-directional flow, as shown in Figure 1.1(b). Here a secondary handling system is provided at each workstation to separate most of the parts from the primary line. Material handling equipment used: in-line transfer system; conveyor system; or rail-guided vehicle system.



(a)

(b)

Figure 1.1: In line FMS layout

1.3.2. Loop FMS layout

Workstations are organized in a loop that is served by a looped parts handling system. In Figure 2, parts usually flow in one direction around the loop with the capability to stop and be transferred to any station.

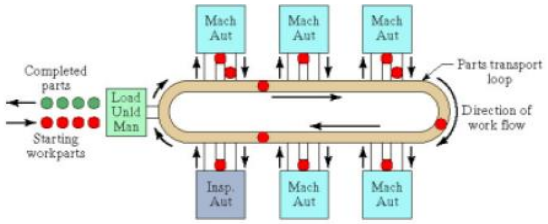


Figure 1.2: Loop FMS layout

Each station has secondary handling equipment so that part can be brought-to and transferred from the station work head to the material handling loop. Load/unload stations are usually located at one end of the loop.

1.3.3. Rectangular FMS layout

This arrangement allows for the return of pallets to the starting position in a straight line arrangement. See Figure 1.3.

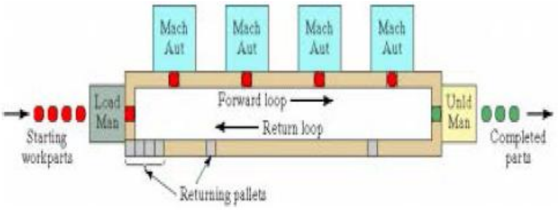


Figure 1.3: Rectangular FMS layout

1.3.4. Ladder FMS layout

This consists of a loop with rungs upon which workstations are located. The rungs increase the number of possible ways of getting from one machine to the next, and obviate the need for a secondary material handling system. It reduces average travel distance and minimizes congestion in the handling system, thereby reducing transport time between stations. See Figure 1.4.

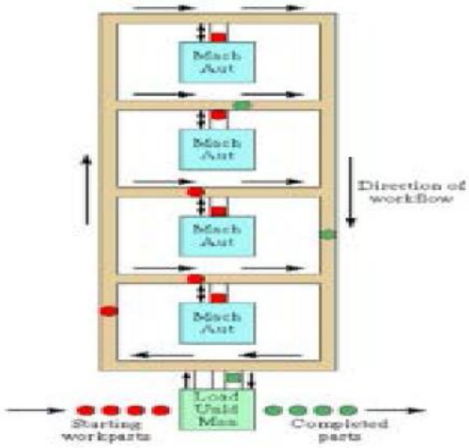


Figure1.4: Ladder FMS layout

1.3.5. Open Field FMS layout

It consists of multiple loops and ladders, and may include sidings also. This layout is generally used to process a large family of parts, although the number of different machine types may be limited, and parts are usually routed to different workstations depending on which one becomes available first. See Figure 1.5.

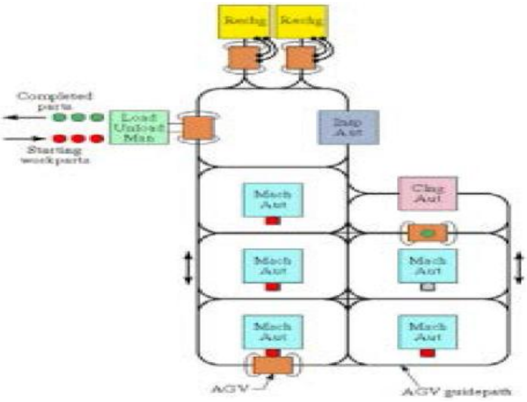


Figure 1.5: Open field FMS layout

1.3.6. Robot centred FMS layout

This layout uses one or more robots as the material handling system. See figure 1.6.

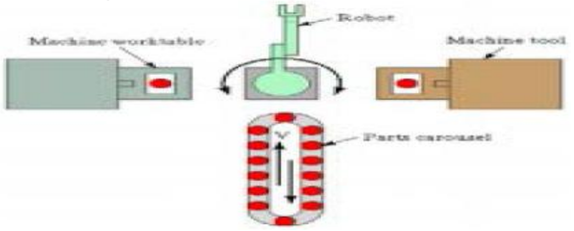


Figure 1.6: Robot centered FMS layout

1.4. Objectives of research

The primary goal of any manufacturing industry is to achieve a high level of productivity and flexibility which can only be done in a computer integrated manufacturing environment. The objective of this research is to maximize machine utilization, maximizing throughput of system and optimize factors those affects system utilization and throughput of system by using Taguchi philosophy and genetic algorithm.

II. LITERATURE SURVEY

Han et al. [8] presents the setup and scheduling problem in a special type of flexible manufacturing system, 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, there were limited tools. The objective 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 flexible manufacturing system investigated by Han et al., is special. All machine tools are assumed identical. Hence, the jobs remain at one machine, and the tools are moved to the machines as needed. Kimemia and Gershwin [9] report on an optimization problem that optimizes the routing of the parts in a flexible manufacturing system with the objective of maximizing the flow while keeping the average in-process inventory below a fixed level. Operation has different processing time for different machines in cell. Network of queues approach is used. The technique showed good results in simulation. Chen and Chung [10] evaluate loading formulations and routing policies in a simulated environment. Their main finding was that flexible manufacturing system is not superior to job shop if the routing flexibility is not utilized. Avonts and Van Wassenhove [11] 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.

III. METHODOLOGY

In this research methodology has been adopted as shown in figure 3.1, it starts with scheduling of job by using sequencing rules, and then according to scheduling a simulated small flexible manufacturing has been developed. The process variables those affects FMS objectives were designed by using Taguchi philosophy has been treated as input function for simulation model of FMS to generate the throughput and working hours for each machine per year and then system utilization and throughput has been optimized as discussed below

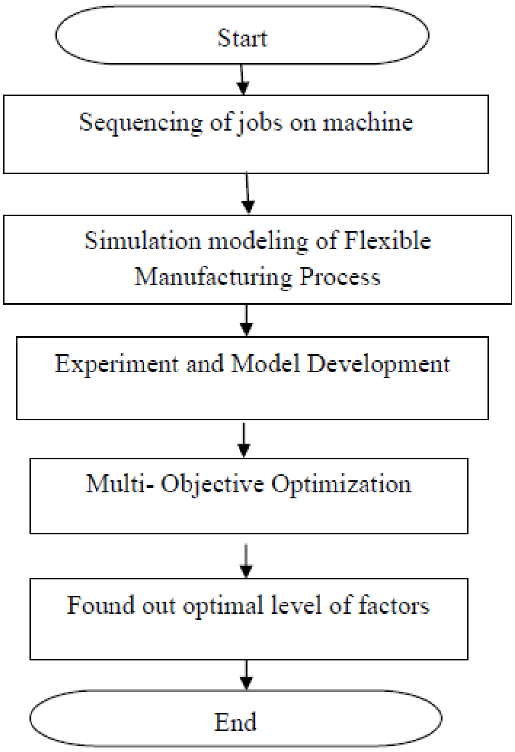


Figure 3.1: flow chart of analysis of jobs

IV. SCHEDULING

In this research, Shortest Processing Time (SPT) has been used. In Shortest Processing Time (SPT), the job which has the smallest operation time enters service first (local rule). SPT rule is simple, fast, generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in-process inventories (less shop congestion) and downstream idle time (higher resource utilization), and usually lower average job tardiness. Scheduling of flexible manufacturing system according to SPT rule is as shown in table 1. According to this sequence make span is 12 min.

Table 1: Sequencing of operation on jobs

M/C_k	Sequence of operation
M/C_1	O_{21}-O_{41}-O_{23}
M/C_2	O_{12}-O_{42}-O_{32}
M/C_3	O_{31}
M/C_4	O_{11}- O_{13}-O_{33}-O_{34}
M/C_4	O_{22}

4.2. Experimental design

In this research L27 array has been used as discussed in previous chapter. When the process variable designed by using Taguchi philosophy has been treated as input function for simulation model of FMS to generate the working hours for every machine per year, and also gives the throughput of system. According to objective of FMS throughput and system utilization are larger is better. So using larger is better in L27 array in Taguchi philosophy following plots and regression equations obtained.

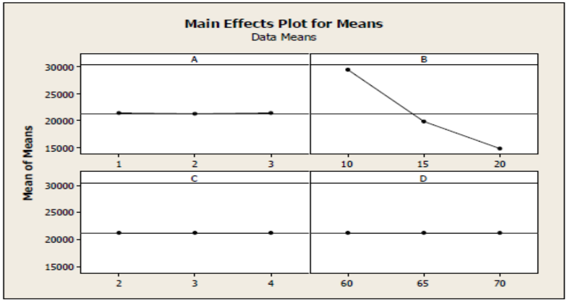


Figure 4.1: Main effect plot for means of throughput of system

Main effect plot for means of throughput shows that distance preference should be at first level means distance preference should be smallest for this simulated flexible manufacturing system for maximizing throughput of system and throughput of system is maximum at demand time is 10 min. and no. of carts is 4 and velocity of cart is 65 feet/min.

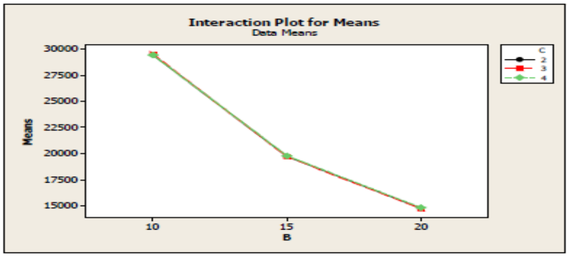


Figure 4.2: Interaction plots between demand arrival time (B) and no. of carts(C) for throughput Interaction plots for means between demand arrival demand time (B) and no. of carts (C) gives that as arrival demand time increases throughput of system decreases there is very less effect of no. of carts on throughput according to this research in this problem.

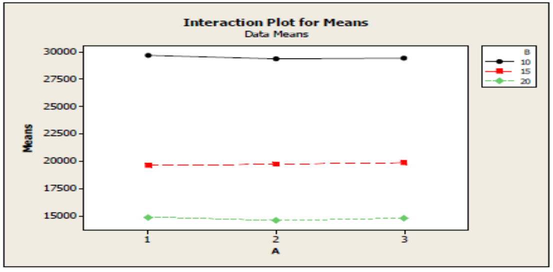


Figure 4.3: Interaction plots between and distance preference (A) and demand arrival time (B) for throughput

Interaction plots for means between demand arrival demand time (B) and distance preference (A) gives that as arrival demand time increases throughput of system decreases and when arrival demand time is 20 min., throughput maximum at level 1 means when the distance preference is smallest but when arrival demand time is 15 min., throughput maximum at level three means the distance preference is cyclical, and when arrival demand time is 10 min. and distance preference is smallest so throughput of system is maximum. It means as arrival time increases, throughput of system decreases

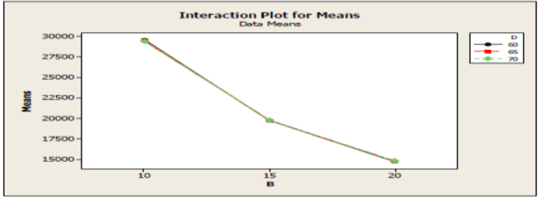


Figure 4.4: Interaction plots for means between demand arrival time (B) and velocity of carts (D) for system throughput.

Interaction plots for means between demand arrival demand time (B) and velocity of carts (D) gives that as arrival demand time increases throughput of system decreases there is very less effect of velocity of carts on throughput according to this research in this problem.

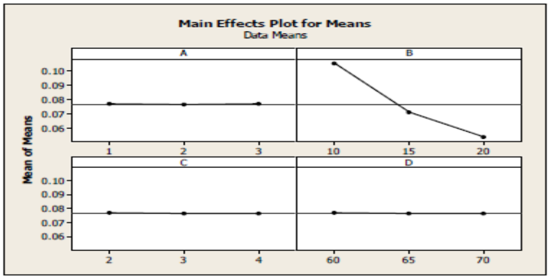


Figure 4.5: Main effect plot for means of system utilization

Main effect plot of system utilization shows that distance preference should be at first level means distance preference should be smallest for this simulated flexible manufacturing system for maximizing system utilization of system is maximum at demand time is 10 min. and no. of carts is 2 and velocity of cart is 60 feet/min.

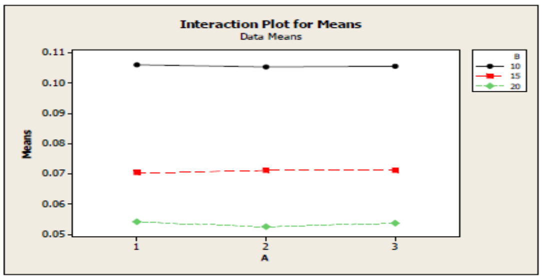


Figure 4.5: Interaction plots for means between and distance preference (A) and demand arrival time (B) for system utilization.

Interaction plots for means between demand arrival demand time (B) and distance preference (A) gives that as arrival demand time increases throughput of system decreases and when arrival demand time is 20 min., throughput maximum at level 1 means when the distance preference is smallest but when arrival demand time is 15 min., throughput maximum at level three means the distance preference is cyclical, and when arrival demand time is 10 min. and distance preference is smallest so throughput of system is maximum. It means as arrival time increases, throughput of system decreases

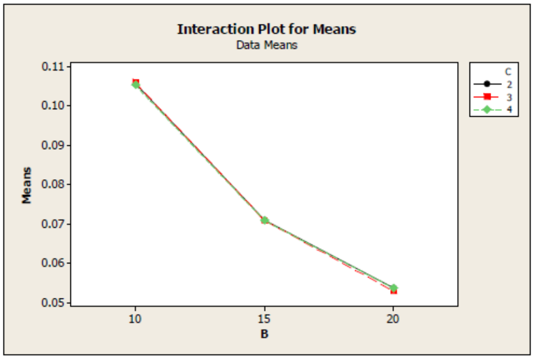


Figure 4.6: Interaction plots for means between demand arrival time (B) and no. of carts(C) for system utilization.

Interaction plots for means between demand arrival demand time (B) and no. of carts (C) gives that as arrival demand time increases throughput of system decreases there is very less effect of no. of carts on system utilization according to this research in this problem.

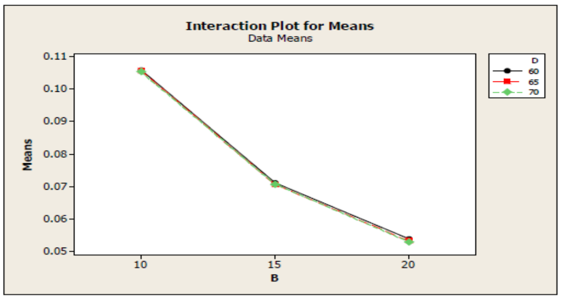


Figure 4.7: Interaction plots for means between demand arrival time (B) and velocity of carts (D) for system utilization.

Interaction plots for means between demand arrival demand time (B) and velocity of carts (D) gives that as arrival demand time increases throughput of system decreases there is very less effect of velocity of carts on throughput according to this research in this problem.

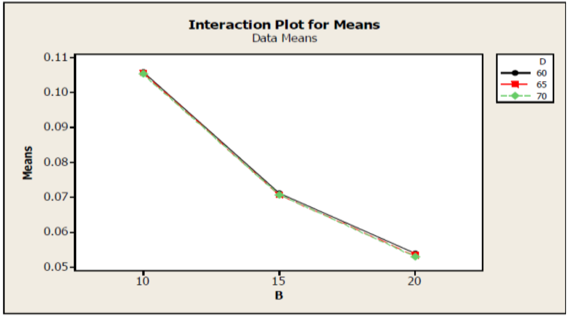


Fig 4.8-Interaction plots for means between demand arrival time (B) and velocity of carts (D) for system utilization.

As shown in response table for means gives that demand time is more influencing factor than other factors. Than velocity of carts affects the system utilization and distance preference is very less influencing factor for throughput.

Table 2: Response table for means for throughput

Level	A	B	C	D
1	0.07681	0.10573	0.07675	0.07697
2	0.07628	0.07086	0.07659	0.07659
3	0.07684	0.05334	0.0766	0.07638
Delta	0.00056	0.05239	0.00016	0.0006
Rank	3	1	4	2

As shown in response table for means gives that demand time is more influencing factor than other factors. Than velocity of carts affects the system utilization and distance preference is very less influencing factor for system utilization

Table 3: Response table for system utilization

Level	A	B	C	D
1	21373	29453	21295	21315
2	21235	19732	21318	21317
3	21340	14763	21334	21316
Delta	138	14690	39	2
Rank	2	1	3	4

V. CONCLUSION & FUTURE SCOPE

In this research, we presented a simulation modeling and optimization of FMS objectives for evaluating the effect of factors such as demand arrival time, no. of carts used in system, velocity of carts, and distance preference between two stations. System utilization and throughput both are affected by these factors. System utilization and throughput is more affected by demand arrival time comparatively other three factors. Distance preference also affects throughput and system utilization. For both system utilization and throughput distance preference should be smallest. And as the demand arrival time increases both system utilization and throughput of system decreases. No of carts and velocity of carts are less affected.

The problems here solved are solved by following Genetic Algorithm. It is also observed that use of Genetic algorithm in integration with other meta heuristics like Tabu search, simulated annealing, neural networks to determine the optimized schedule in an FMS. It can also be solved by various other techniques such as particle Swarm Optimization and many others. Another approach can also be by following Adaptive Genetic Algorithm or by following higher Heuristic Approach. Generally, jobs are scheduled but simultaneous scheduling of jobs and machines remains the most interesting area to work on and this can do wonders to our industrial life. In this case, both, jobs and machines will work together and the make span time can be drastically reduced. It is also observed that use of Genetic algorithm in integration with other meta heuristics like Tabu search, simulated annealing, neural networks to determine the optimized schedule in an FMS.

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