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Production planning in Flexible Manufacturing System by considering the Multi-Objectives

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Abstract: Flexible Manufacturing System (FMS) provides the manufacturing industries to the necessary flexibility and ability to cope up with the current demands defined by the market needs. An FMS usually comprises of four or more work stations which are mechanically interconnected by a unique part handling system and electronically controlled by a distributed controlled system. The operation and control of FMS having many challenges associated with them, which can be categorized into four stages such as designed stage, system setup, scheduling and control stage. Because of inherent flexibility of FMS, there are number of alternates available to the choice of machine to perform a particular operation. The flexibility of FMS system gives many alternative routings. In order to maintain the throughput and efficiency, it is very important to choose the best available route from the multiple routing options. In this paper I considered a case study of FMS in which, three flexible machines and three kinds of products (or) parts are to be machined. I assumed that a machine can do all kinds of operations and Part A have four, Part B have three, and Part C have three machining operations. The machining time and cost of machining is different from each operation. We used Mathematical calculations to minimize the total machining time and tool cost of the Flexible Manufacturing system.

Keywords: Flexible Manufacturing system, Multi-objective optimization, Tool cost, Machining time, Failure of machines.

1. INTRODUCTION

The Flexible manufacturing system usually consists of four or more processing stations like turning center, milling center, horizontal machine center, vertical machine center etc., which are interlinked by a common part handling system(AGVs, Robots) as well as tool handling systems (Tool magazine, Automatic tool changer) and automatically controlled by a distributed computer system. It also includes automatic pallet changes, coordinate measuring machine and automatic scrap removal.

Flexible manufacturing system scheduling could be well thought-out as a static scheduling problem, where a fixed set of orders are to be scheduled by using optimization or main concern scheduling. On the other hand, this could also be viewed as a dynamic scheduling problem, where orders arrive periodically for scheduling as daily orders are released from a material requirement planning system or as individual customer’s order. The prime importance of FMS scheduling is to enhance the utilization of resources, thereby reducing the idle time and in process inventory by having efficient and effective utilization of resources. Scheduling helps to achieve its strategic objectives. In practical enumeration procedures coupled with high cost have made it extremely difficult to generate consistently good schedules in medium to large shops.

One can employ multiple approaches to schedule the manufacture of parts to a system. These approaches may vary from system to system and are different for different situations. Some of these approaches include the following:

- To determine the optimal sequence at which the parts of a selected part types are to be given as input into the system. At times these part types must be produced in certain relative ratios. For certain types of FMS systems, it will be appropriate to maintain the periodic input sequence. Sometimes, maintaining a fixed production ratio of part types on the systems may also be considered. Some of the operations can be scheduled by having a fixed predetermined input sequence. While for other operations, a flexible real time decision categorizes for which part has to be given as input for the next sequence should be incorporated.

- It is very important to develop appropriate scheduling methods and algorithms. Tools to aid scheduling can range from simple dispatching rules to complex algorithms or procedures incorporated for the future.
- In some cases, when different parts are waiting to be processed by the same machine tool, it is important to identify the priority among these parts. In most of the situations, it will be appropriate to determine an optimal sequence at each machine tool. Many of the usual performance measures such as maximizing the productivity, optimizing a machine utilization time, minimizing the inventory, reaching the due date in the system are relevant.

2. LITERATURE REVIEW

Jian- Hung Chen, Shinn-Ying Ho proposed an efficient multi objective genetic algorithm EMOGA for planning flexible manufacturing system of FMS. Minimizing total flow time, machine workload imbalance, greatest machine workload and total tool cost are the four objectives they considered in problem formulation. This problem solved the complex nature by using more than one product, more than one operation, and cost. The convenience of this problem is it can set the preferences among the objective functions [1].

Carl Adam Petri in 1962 formulated the standard Petri net model. It handled many issues like concurrency, running of machines in parallel, resources sharing, synchronization, and sequential actions. Its main defect is that it can’t solve multi-sort manufacturing processes in a timed context; timed colored Petri nets are used to solve such situations [2].

Manufacturing process is a thing of the most unexpected uncertainties such as unexpected events, sudden or un indicated machine break downs, sudden surplus orders, order cancellations ets. In spite of the complex nature, the FMS can be planned efficiently with program formulations [3].

K.Mallikarjuna et al studied the machines arranged in single row assisted by AVG. the programming is made by Simulated Annealing (SA) and Genetic Algorithm. The results obtained by GA are superior to SA. The parameter like transportation cost with machine sequences is determined for single row layout by running the program for five test runs [4].

Imran Ali Chaudhry et al programmed a no waiting flow shop problem. They prepared spreadsheet for the general purpose GA methodology, it was simple and very effective to implement in shop floor. This spreadsheet is prepared to accept the additional workers, machines without changing the logic of the GA route [5].

Rajkiran Bramhane et al studied the FMS with fuzzy logics and neuro techniques. They considered a system with four machines; one AGV, one loadd and one unload station. The job is given priority based on S/RO parameter [6].

Omar Selt concluded that, good neighborhood diversification will give best possible and accurate results in FMS. He solved the problem of n tasks on a single machine. To make a comparative study he proposed two heuristics [7].

3. PROBLEM STATEMENT

In this paper we focus on operation flexibility in the production planning segment of FMS. Operation flexibility is related with an operation which can be performed on alternative machines with different processing time, transportation time and machining costs. Therefore, optimizations on routing, machines are essential for operation flexibility. The sample problem we took from the literature of Jian-Hung Chen, Shinn-Ying Ho papers about assignment of operations to machines for two objectives, minimizing total flow time and total tool cost are considered in our problems.

Operation Index		Part 1				Part 2			Part 3		
		1	2	3	4	1	2	3	1	2	3
Processing Time	Machine 1	1	3	3	5	9	2	9	7	8	7
	Machine 2	7	5	4	6	4	1	4	1	6	2
	Machine 3	6	9	5	1	2	5	1	3	3	5
Machining cost	Machine 1	1	2	1	6	1	8	4	8	3	6
	Machine 2	2	3	7	5	9	2	5	9	8	5
	Machine 3	4	5	4	2	8	7	8	9	6	2
Production volume		51				39			23		

Table.1 Processing time, Machining costs of different operations on 3 machines and production volume of 3 parts

	Machine 1	Machine 2	Machine 3
Machine 1	4	11	17
Machine 2	11	3	9
Machine 3	7	18	5

Table 2 Travelling time between the Machines

The scheduling of production process by using flexible manufacturing system using three machines with different processing and travelling time at different costs is studied by a numerical calculation. The complexity of the investigation is scheduling problem in FMS by assuming that all machines are working properly and then some of the machines were stopped working. All these calculations are done by taking different machine indices randomly, large calculations are done.

4. MATHEMATICAL CALCULATIONS

Nomenclature

t1 = Total processing time of three parts in required Production quantity.
t2 = Total transportation time in between machines.
F1 = (t1+t2) = Total machining and Transportation time.
F2 = Minimization of total too cost.

Sample calculations for

Part Index	**1**	**2**	**3**
Operation Index	**1234**	**123**	**123**
Machine Index	1233	123	132

Step I

a. To find t1 calculations :
   t1 = 51 x (1+5+5+1) + 39 x (9+1+1) + 23 x (7+3+2)
   = 51 x 12 + 39 x 11 + 23 x 12
   = 612 + 429 + 276 = 1317.
b. To find t2:
   t1 = 51/10 x (11+9+5) + 39/10 x (11+9) + 23/10 x (17+18)
   = 5.1 x 25 + 3.9 x 20 + 2.3 x 35
   = 127.5 + 78 + 80.5
   = 286.
   F1 = f1 + f2
   = 1317 + 286 = 1603.

Step II to find F2:

F2 = (1+3+4+2) + (1+2+8) + (8+6+5)
= 10 + 11 + 19 = 40

5. RESULTS AND DISCUSSIONS

5.1 Results

The proposed approach can be used to study the optimization in case of failure of few machines. Results for random sequence of operations,

	Operation Index			Total Time			Tool Cost
Description	**Part 1**	**Part 2**	**Part 3**	**t1**	**t2**	**F1=t1+t2**	**F2**
All Machine Working	1233	123	132	1317	286.0	1603	40
All Machine Working	2232	321	213	1963	330.5	2293.5	42
All Machine Working	3211	213	123	1656	323.5	1979.5	57
All Machine Working	3221	312	321	1700	300.1	2000.1	64
All Machine Working	3213	132	312	1766	412.5	2178.5	40
All Machine Working	1322	231	132	1998	336.7	2334.7	57
All Machine Working	1332	321	231	1792	353.9	2145.9	50
All Machine Working	2123	123	213	1516	249.5	1765.5	38
All Machine Working	2132	213	321	1712	410.5	2122.5	61
All Machine Working	1321	132	123	2085	417.1	2502.1	50

Table 3 –Total time and Tool cost when all machines are working

	Operation Index			Total Time			Tool Cost
Description	**Part 1**	**Part 2**	**Part 3**	**t1**	**t2**	**F1=t1+t2**	**F2**
Machine 1 Fails	2323	223	323	1627	292.5	1919.5	54
Machine 1 Fails	2332	322	332	1834	298.0	2132	52
Machine 1 Fails	2232	233	322	1816	255.9	2071.9	60
Machine 1 Fails	2233	232	233	1632	224.2	1856.2	56
Machine 1 Fails	2322	332	232	1893	304.8	2197.8	59
Machine 1 Fails	3323	323	223	1452	296.1	1748.1	55
Machine 1 Fails	3223	223	323	1372	261.9	1633.9	54
Machine 1 Fails	3332	233	332	1900	250.3	2150.3	62
Machine 1 Fails	3232	332	322	1804	367.5	2171.5	58
Machine 1 Fails	3233	323	233	1230	300.7	1530.7	48

Table 4 –Total time and Tool cost when machine 1 fails

	Operation Index			Total Time			Tool Cost
Description	**Part 1**	**Part 2**	**Part 3**	**t1**	**t2**	**F1=t1+t2**	**F2**
Machine 2 Fails	1131	113	313	1550	279.9	1829.9	44
Machine 2 Fails	3111	331	133	1836	173.9	2009.9	48
Machine 2 Fails	1311	131	331	2114	264.0	2378	46
Machine 2 Fails	3113	313	131	1249	291.6	1540.6	53
Machine 2 Fails	1113	133	113	1453	261.6	1714.6	35

Machine 2 Fails	3131	311	313	1844	244.5	2088.5	50
Machine 2 Fails	1133	131	113	1867	274.5	2141.5	34
Machine 2 Fails	3133	313	311	1374	266.8	1640.8	54
Machine 2 Fails	1313	113	331	1481	318.6	1799.6	47
Machine 2 Fails	3311	331	131	2188	183.6	2371.6	55

Table 5 –Total time and Tool cost when machine 2 fails

	Operation Index			**Total Time**			**Tool Cost**
Description	**Part 1**	**Part 2**	**Part 3**	**t1**	**t2**	**F1=t1+t2**	**F2**
Machine 3 Fails	2211	212	112	1801	212.1	2013.1	50
Machine 3 Fails	1212	122	221	1633	255.1	1888.1	41
Machine 3 Fails	2122	121	212	2014	263.9	2277.9	40
Machine 3 Fails	1122	221	121	1720	197.0	1917	52
Machine 3 Fails	2121	112	122	1899	259.0	2158	52
Machine 3 Fails	1112	212	211	1421	217.2	1638.2	49
Machine 3 Fails	2112	112	121	2014	241.7	2255.7	46
Machine 3 Fails	1211	211	212	1552	241.7	1793.7	49
Machine 3 Fails	2111	221	112	1855	186.0	2041	42
Machine 3 Fails	1121	121	221	1726	250.6	1976.6	46

Table 6 –Total time and Tool cost when machine 3 fails

	Operation Index			**Total Time**			**Tool Cost**
Description	**Part 1**	**Part 2**	**Part 3**	**t1**	**t2**	**F1=t1+t2**	**F2**
M1 Partially fails	2323	132	123	2187	366.1	2553.1	47
M1 Partially fails	3233	321	213	1657	340.7	1997.7	41
M1 Partially fails	2332	123	321	2174	307.9	2481.9	51
M1 Partially fails	3232	213	132	1671	419.2	2090.2	60
M1 Partially fails	2232	312	123	1899	269.2	2168.2	53
M1 Partially fails	3332	231	312	2327	246.6	2573.6	55
M1 Partially fails	2233	321	213	1708	264.2	1972.2	39
M1 Partially fails	3223	132	321	1886	356.2	2242.2	52
M1 Partially fails	2322	123	132	2031	311.5	2342.5	47
M1 Partially fails	3323	213	123	1707	318.4	2025.4	61

Table 7 –Total time and Tool cost when machine 1 fails partially

	Operation Index			**Total Time**			**Tool Cost**
Description	**Part 1**	**Part 2**	**Part 3**	**Description**	**Part 1**	**Part 2**	**Part 3**
M2 Partially fails	3311	312	132	1761	232.3	1993.3	56
M2 Partially fails	1313	321	123	1596	368.2	1964.2	41
M2 Partially fails	3133	213	321	1406	323.8	1729.8	60
M2 Partially fails	1133	132	213	1534	333.5	1867.5	36
M2 Partially fails	3131	123	132	1674	316.6	1990.6	46
M2 Partially fails	1113	231	312	1409	231.3	1640.3	43
M2 Partially fails	3113	321	231	1384	292.7	1676.7	44
M2 Partially fails	1311	132	123	2034	325.3	2359.3	44
M2 Partially fails	3111	213	321	1508	252.4	1760.4	61

M2 Partially fails	1131	123	213	1465	285.2	1750.2	41

Table 8 –Total time and Tool cost when machine 2 fails partially

	Operation Index			Total Time			Tool Cost
Description	**Part 1**	**Part 2**	**Part 3**	**Description**	**Part 1**	**Part 2**	**Part 3**
M3 Partially fails	1211	123	132	1419	291.1	1710.1	41
M3 Partially fails	2112	321	213	1759	310.1	2069.1	38
M3 Partially fails	2211	213	123	1707	247.0	1954	55
M3 Partially fails	1212	132	321	1835	371.5	2206.5	46
M3 Partially fails	2121	231	132	1947	311.2	2258.2	56
M3 Partially fails	1112	312	231	1228	203.9	1431.9	51
M3 Partially fails	2122	321	312	1787	282.0	2069	47
M3 Partially fails	1122	123	213	1465	234.2	1699.2	40
M3 Partially fails	2111	213	123	1605	252.1	1857.1	54
M3 Partially fails	1121	132	321	1733	335.8	2068.8	52

Table 8 –Total time and Tool cost when machine 2 fails partially

5.2 Discussion

Formulation of problem:

In this paper, an attempt is made by considering some additional constrains like all machines are working, first machine is not working, second machine is not working, and third machine is not working.

We also done the calculations related to the conditions when any one of the machine get stopped working, like machine one partially failed, machine two partially failed and machine three partially failed. These working conditions are considered by taking the various operational indices on different machines by randomly selection. By taking all these constraints, corresponding objective function values i.e.F1 and F2 are calculated.

Another important constraint we have taken is a machine does not work while manufacturing a particular product, but it works while manufacturing of other two products. We have also considered other conditions like, Machine 1 completely fails, Machine 2 completely fails and Machine 3 fails completely.

- **When all machines are working:** The results show that operation index 1233, 123, 132 gives the least manufacturing time for manufacturing of three types of products. And this operation index gives the minimum total tool cost.
- **When machine one fails:** The results show that operation index 3233, 323, 233 gives the least manufacturing time for manufacturing of three types of products, and this operation index gives the minimum total tool cost.
- **When machine two fails:** The results show that operation index 3113, 313, 131 gives the least manufacturing time for manufacturing of three types of products, and the operation index 1131, 113, 313 gives the total tool cost minimum.
- **When machine three fails:** The results show that operation index 1112, 212, 211 gives the least manufacturing time for manufacturing of three types of products, and the operation index 2122, 121, 212 gives the total tool cost minimum.
- **When machine one partially fails:** The results show that operation index 2233, 321, 213 gives the least manufacturing time for manufacturing of three types of products, and this operation index gives the minimum total tool cost.
- **When machine two partially fails:** The results show that operation index 1113, 231, 312 gives the least manufacturing time for manufacturing of three types of products, and operation index 1133, 132, 213 gives the total tool cost minimum.
- **When machine three partially fails:** The results show that operation index 1112, 312, 231 gives the least manufacturing time for manufacturing of three types of products, and operation index 2112, 321, 213 gives the total tool cost minimum.

6. CONCLUSIONS

The paper identified the different operations index on machines in production planning of Flexible manufacturing system by considering the objective functions as minimizing the manufacturing time, flow time and total tool cost. The objective function values are calculated for randomly selected operation index sequence when all the three machines are working, when machine one fails, machine two fails, machine three fails and machine one partially fails, machine two partially fails, machine partially fails. The results show that when all the machines are working, the objective function values are better for operations indexes 1233, 123, 132 for manufacturing of three parts i.e. Part A, B&C. From the tabulated results it is observed that when machine one fails the values of F1, F2 i.e. total flow time and tool cost is better than the machine two and machine three fails that means it is advisable to maintain the machine two, three properly to avoid failures. The tool cost that is F2 is better when machine two fails and machine three partially fails. From the results it is observed that any one single operation index is not fulfilling both the objectives. But we can suggest the best operation index for the minimization of total flow time and tool cost. Depending upon their objective function we can select the operation index while doing the production planning. In future we are planning to develop an algorithm for identifying better operation index that depending on the objective function that can be achieved when all machines are working or if any one of the machine get failed.

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