International Journal of Advanced Mechanical Engineering.
ISSN 2250-3234 Volume 4, Number 2 (2014), pp. 185-192

http://www.ripublication.com/ijame.htm

A Real-time Methodology for Minimizing Flow Time in FMS with Full Routing Flexibility

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Abstract

A real time methodology with full routing flexibility is used for minimizing mean flow time in FMS. The combination of flexible alternative machines and flexible alternative operation sequences are used to obtain the full routing flexibility in flexible manufacturing system. Full routing flexibility offers decreasing cost, reducing waiting time and increasing efficiency. This paper presents an efficient continuous real-time routing strategy, namely full routing flexibility to minimise the system unbalance and maximise the system throughput by balancing the workload. Full routing flexibility provides significant improvement in system performance and shows how the routing control policies influence the system performance.

Keywords: Flexible manufacturing systems: Routing flexibility: Alternate routings: alternate machine selection: scheduling: ARENA simulation.

1. Introduction

Flexible Manufacturing is a concept that allows manufacturing systems to be built under high customized production requirements. The issues such as reduction in waiting time, market-response time to meet customer demand, productivity and flexibility are the primary goal of today‘s production technology. These can only be achieved in fully integrated manufacturing environments. A flexible manufacturing system (FMS) is an integrated computer-controlled configuration which consists of numerical control (NC) machine tools, auxiliary production equipment and a material handling system (MHS). It is designed to manufacture a low to medium volumes of a mid variety of high quality products at low cost simultaneously. The flexibility dimension in a FMS can be characterized into four categories: (1) no routing flexibility (2) flexible alternate machines (3) flexible alternative operations sequences (4) full routing flexibility. An FMS can be defined as a computer-controlled configuration of semi-dependent workstations and material-handling systems designed to efficiently manufacture various part types with low to medium volume. It combines high levels of flexibility with high productivity and low level of work- in-process inventory Jang (1996), The need for flexibility, efficiency, and quality has imposed a major change in manufacturing industries. An FMS can be considered flexible if it is able to process parts as and when they arrive into the system. To achieve that the material handling system needs to have sufficient capacity and the machines need to have sufficient tools of various types to handle the variety of parts Kashyap(1996). One of the objectives of an FMS is to achieve the flexibility of low volume production while retaining the efficiency of high-volume mass production Roh(1997).

2. Litrature Review

To justify a relatively high investment in a flexible manufacturing system's, it is of utmost importance to make full use of the flexibilities that the FMS offers. An FMS is designed to manufacture a variety of items and to provide alternative processing routes for individual products. Shankar (1991) resolved the problem of the real time operation control by part entry selection. Chandra (1992), Bobrowski (1988) resolved this problem by using alternate routing selection. Lin and Solberg (1989); Arzi and Roll (1993) introduced alternate operation selection in FMS. Sethi (1990) used routing flexibility in FMS i.e. the ability to produce a part by alternate routes through the system. Brown et al. (1984) introduced alternate routes includes the use of different machines to perform the same operation, alternate operations to perform the given task, or different sequences of operations. Hutchinson (1994) explain that in conventional system there is little incentive to consider flexible process plan because of the cost of their development, the lack of dynamic knowledge- based control system to implement them, and their unknown benefits. In contrast, the existence of advanced information and manufacturing technologies in FMSs provide all the capabilities necessary to implement flexible process plans. Flexible process plans could be considered as one potential way of improving system performance. Ammos, (1985) resolve the real time operational control considering two objectives, namely balancing workload and minimizing work stations visits. Bryne, (1997) The operational control in FMS with flexible alternative machines and flexible alternative operation sequences (full routing flexible) ,Kim (1997) have found that throughput maximization by balancing the workloads on the machine often results in limiting the tardiness. Seda (2005) they introduced a real time methodology for minimizing mean flow time in FMSs with routing flexibility using threshold- based alternate routing.

It is seen from the literature review that very few studies are reported that deal with the impact of routing flexibility, under different variables, such as sequencing rule, dispatching rule, etc., on the system performance. In this paper the combination of flexible alternate machines and flexible alternative operations sequences are used to obtain the full routing flexibility in the FMS. The modelling and simulation tool used in present work, namely ARENA, helps to develop the simulation model and shows the various factors that affects on the system performance

3. Problem Formulation and Methodlogy

The objective of this paper is to investigate how routing control polices influence the system performance under various operating conditions. In principle, where full routing flexibility exist the remaining operations for the part can be performed in any order, and the next operation to be selected can be performed on any one of several alternative machines. This kind of flexibility leads to potential improvement in system performance. The operational control of FMS can be divided into three decision areas: part entry selection, alternate routing selection and alternate operation selection. Routing flexibility i.e. the ability to produce a part by alternate routes through the system. It is an important property of the FMS that increases the decision domains and provides the potential for improved performance by better balancing machine workloads. Alternate routes includes the use of different machines to perform the same operation, alternate operations to perform the given task or different sequences of operations.

Simulation methodology is proposed in present study to minimize the mean flow time of parts by making a selection among alternate routes based on the concept of the significant benefits in terms of waiting time of parts.Development of the simulation model proceeds through various stages, such as setting of scope and objectives, gathering of data, building, verifying, and validating the model, and analyzing its output. Each of these steps is essential for simulation project success Robinson,(1995). Simulation modeling is useful to analyze complex systems such as flexible systems. The objective of this study to minimize the system unbalance and maximize the system throughput by balancing the workload. The simulation software ARENA helps to develop a simulation model for the purpose understanding the behaviour of the system and to explore the impact of routing flexibility

ARENA provides an integrated framework for building simulation models in a wide variety of applications. The ARENA modeling system is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system. ARENA employs an object-oriented design for entirely graphical model development. In Arena, the user builds an experiment model by placing modules (boxes of different shapes) that represent processes or logic, connector lines to join these modules together specifying the flow of entities. Statistical data, such as cycle time and WIP (work in process) levels, can be recorded and output as reports Simulation analysts place graphical objects, called modules, on a layout in order to define system components such as machines, operators, and material handling devices.

3.1 Simulation Model

The flexibility model used is based on objectives of combination of flexible alternate machines and flexible alternative operations to investigate the understanding and behaviour of the system in order to explore the impact of routing flexibility The four flexible machines as per layout shown in figure-1 processing three part types of finite size and undergoing six different operations $O_1 \ldots O_6$ have been considered with following system assumptions:

3.2 System assumptions

1. Each machine can process only one job at a time.
2. Machines are alternative to each other and are prone to failure.
3. Only one machine can be down at a time
4. Machine has input and output buffer and limits of input and output buffers are the same for the different machines. Buffer is arranged randomly.
5. Operation sequences for the job are fixed for a particular part type.
6. Machine sequences for the job are fixed for a particular part type.
7. Each machine arranged in equal distances.
8. Part processing time is normally distributed.
9. Set up times are not sequence dependent.
10. Material handling system consists of unidirectional loop conveyor.
11. There are no tooling constraints sufficient amount of tools are available.

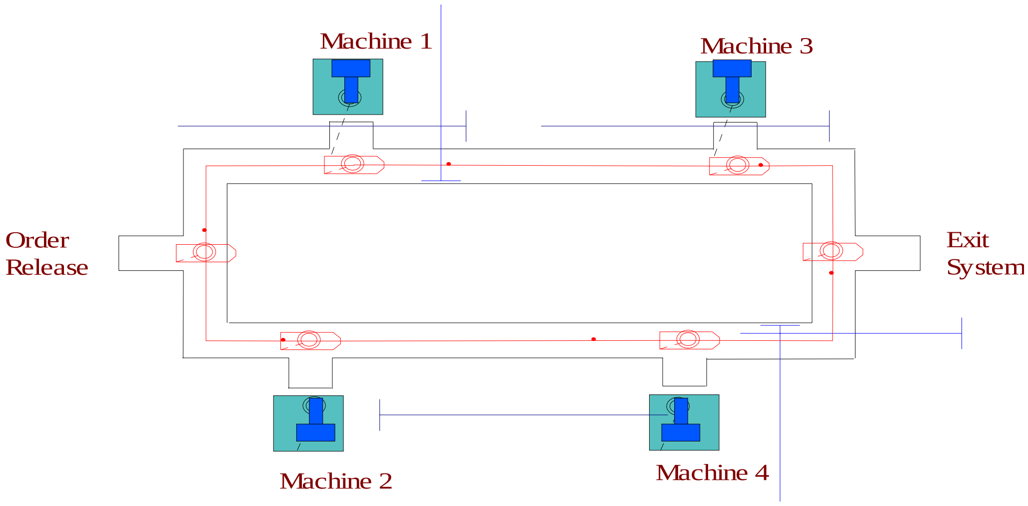


Fig. 1: Proposed FMS Layout.

3.3 Routing strategies

Utilizing the combination of flexible alternate machines and flexible alternate operations to obtaining the full routing flexibility. The principle where the full routing flexibility exists the remaining operation for a part can be perform in any order and the next operation to be selected can be perform on any one of several alternative machines a shown in flow diagrams in the figure-2 . In an ideal condition when there is no machine in loading condition the part can flow through the machines M_1 then M_2 to M_3 then M_4. M_1 perform the operation O_1,O_3,O_5 as well as M_3 also perform O_1 , as M_1 takes minimum time for operation O_1 therefore M_1 is preferred The four stages are depicted in figure-2.

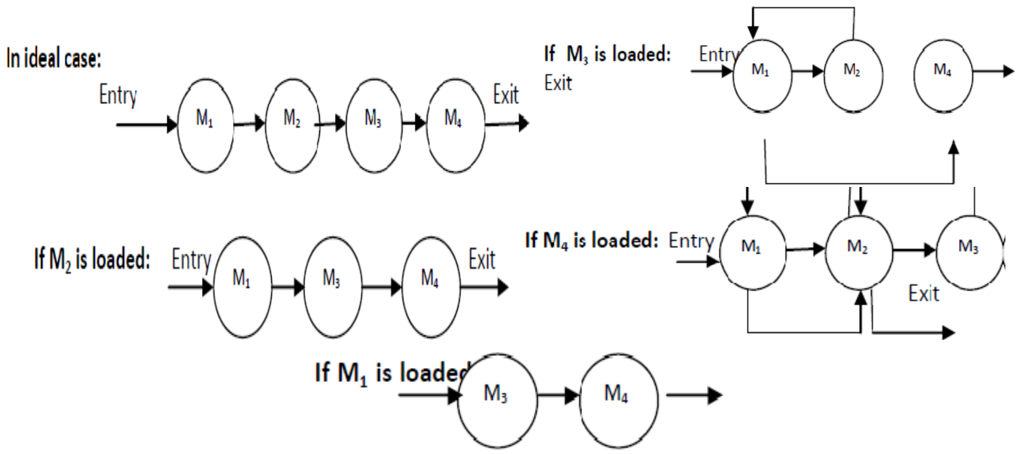


Fig. 2: Routing strategies.

A simulation model considering the routing flexibility as shown in table-1 and alternate machine route as shown in figure-2 and table-2 for different part types have been developed as shown in figure-3 using *ARENA Simulation software V-12*, the various notations used for the heuristic are as follows.

P_i = part type, i= 1, 2, 3,

O_j = no. of operations j = 1, 2, 3, 4, 5, 6,

M_k = no. of flexible alternate machines k = 1, 2, 3, 4.

VA = value added time

NVA= non value added

WIP = work in process

Table 1: Routing for Sequence of Operation for Routing Flexibility.

Parts	O1	O2	O3	O4	O5	O6
P1	M_1 (5), M_3(7)	M_2 (7), M_3 (9)	#	M_4(13),M_2(16)	M_4(9),M_1(10)	#
P2	M_1(5),M_3 (7)	M_2(7),M_3(9)	M_3(11),M_1(15)	#	M_4(9),M_1(10)	#
P3	#	M_2(7),M_3(9)	#	M_4(13), M_2(16)	M_4(9),M_1(10)	M_4(11),M_2(13)

Table 2: Alternate routing machine Flexibility.

Parts	O1	O2	O3	O4	O5	O6
P1	M_1,M_3	M_2,M_3	#	M_4,M_2	M_4,M_1	#
P2	M_1,M_3	M_2,M_3	M_3,M_1	#	M_4,M_1	#
P3	#	M_2,M_3	#	M_4,M_2	M_4,M_1	M_4,M_2

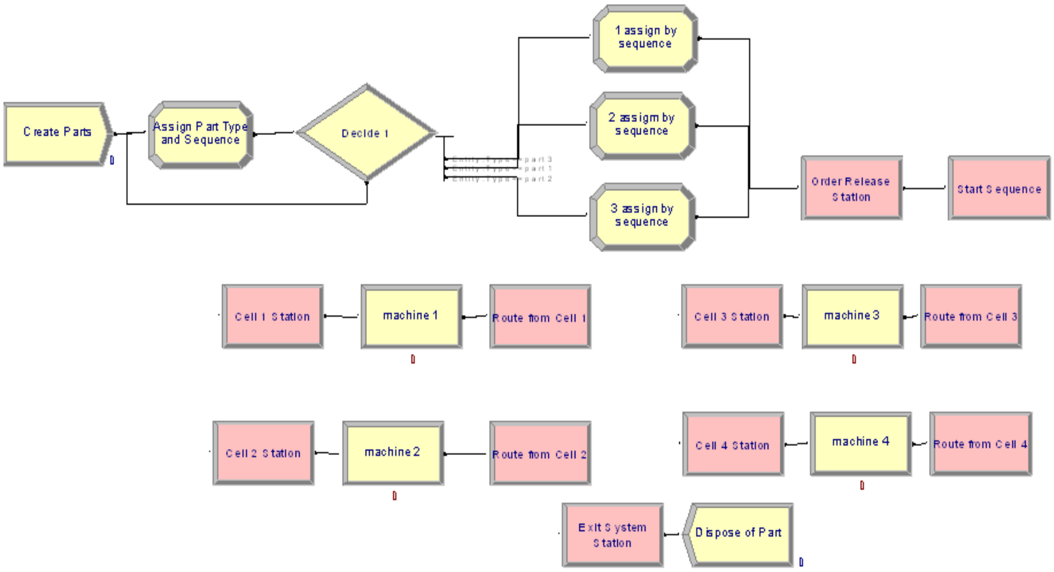


Fig. 3: Developed Simulation Model.

Simulation Result

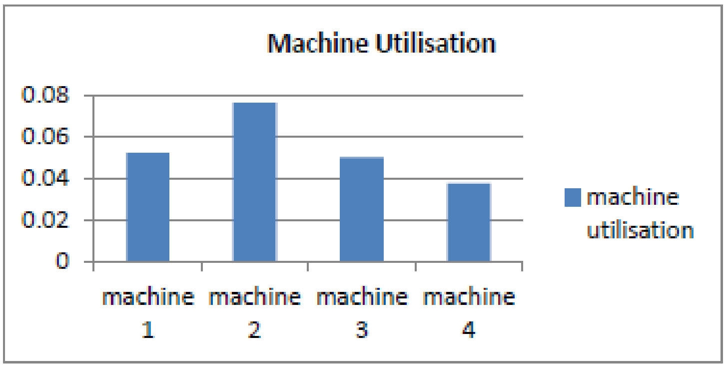
The developed simulation model for 100 parts, flowing through loop conveyor by various routes utilizing full routing flexibility was run in order to investigate machine utilization, reduced the waiting time, mean flow time & significant impact of various factors in the system performance The result for various time, i.e. VA, NVA time, wait time, transfer time etc have been depicted in table-5 and table-4 & table -3shows the result for WIP and number of various parts processed. The machine utilization graph is also mentioned..

Table 3: No of Parts.

WIP	*Average*	*Min value*	*Max value*
Part1	0.2950	0.00	3.0000
Part2	0.8172	0.00	4.0000
Part3	0.4434	0.00	3.0000

Table 4: Work in Process (WIP).

Number in	*value*	*Number out*	*value*
Part1	26.0000	Part1	26.0000
Part2	46.0000	Part2	46.0000
Part3	28.0000	Part3	28.0000



Graph 1: Machine utilization.

Table 5: Various part flow time.

Part type	*VA Time*			*NVA Time*			*Wait Time*			*Transfer Time*			*Total Time*		
	Avg	*Min*	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*	*Max*
P1	6.50	6.50	6.50	0.00	0.0	0.00	0.200	0.050	0.50	15.0865	14.10	16.60	**21.7865**	**20.90**	**23.25**
P2	8.00	8.00	8.00	0.00	0.0	0.00	0.2554	0.050	0.90	25.8533	24.00	27.600	**34.1087**	**32.15**	**35.80**
P3	5.00	5.00	8.00	0.00	0.0	0.00	0.1179	0.00	0.30	25.2839	23.00	26.40	**30.4018**	**28.10**	**31.55**

4. Conclusion

A simulation study is carried out to investigate Machine utilization, number of part types and various part flow time. In this paper full routing flexibility with alternate machine and alternate operation sequences have been introduced. The various factors include full routing flexibility with alternate machines and sequences. Arena simulation package have been employed to perform the analysis. It is seen from the investigations that the proposed model for part type 2 is having maximum waiting time while for part type 1 it is minimum. Also WIP for part type 2 is maximum along with maximum utilisation of machine no 2.Even though this work provides the interesting observations about routing flexibility and machine utilisation, the result of this study should be interpreted with respect to the considered assumptions and experimental conditions. The results obtained will assist the practitioners in selecting the flexibility strategies and machine loading.

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