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Performance measurement of flexible manufacturing system: A case study

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Abstract

A flexible manufacturing system (FMS) is a manufacturing system in which there is flexibility that allows the system to react to changes, whether predicted or unpredicted. It is a highly integrated manufacturing system. The relation between its components is very complex. The mathematical programming approaches are very difficult to solve for very complex system so the simulation of FMS is widely used to analyze its performance measures. Also the FMS components are very sophisticated and costly. If FMS has to be implemented then it is better to analyze its results using simulation which involves no loss of money, resource and labor time. FMS have been studied in aspects as modeling and performance analysis. In this paper, a concept and implementation of the measuring and analysis of performance measures of FMS is applied. Also the system has been modeled. Later the mathematical technique has also been applied for the purpose of comparison and verification of the simulation results. The dispatching problem of FMS is that the performance depends on the state the system is in at each moment, and no single rule exists that is better than the rest in all the possible states that the system may be in. It would therefore be interesting to use the most appropriate dispatching rule at each moment. To achieve this goal, a scheduling approach which uses machine learning can be used.

Keywords: nanotechnology, photochemistry, Spectroscopic methods, Synthesis of materials

1. Introduction

In the present market scenario, the customer demand and specifications of any product changes very rapidly so it is very important for a manufacturing system to accommodate these changes as quickly as possible to be able to compete in the market. This evolution induces often a conflict for a manufacturing system because as the variety is increased the productivity decreases. So the flexible manufacturing system (FMS) is a good combination between variety and productivity. In this system, the main focus is on flexibility rather than the system efficiencies. A competitive FMS is expected to be flexible enough to respond to small batches of customer demand and due to the fact that the construction of any new production line is a large investment so the current production line is reconfigured to keep up with the increased frequency of new product design. The optimal design of FMS is a critical issue and it is a complex problem. There are various modeling techniques for FMS; the most common one are based on mathematical programming. FMS is a highly integrated manufacturing system and the inter-relationships between its various components are not well understood for a very complex system. Due to this complexity, it is difficult to accurately calculate the performance measures of the FMS which leads to its design through mathematical techniques. Therefore, computer simulation is an extensively used numeric modeling technique for the analysis of highly complex flexible manufacturing systems.

2. Literature survey

Browne et al., 1984 defines FMS as an integrated computer controlled system with automated material handling devices and CNC machine-tools and which can be used to simultaneously process a medium-sized volume of a variety of parts. Chan et al. (2007) presented a simulation study using Taguchi's method analysis of physical and operating parameters of the flexible manufacturing system along with flexibility. An approach is developed to study the impact of variations in the physical and operating parameters of an FMS and to identify the level of these variations. The physical and operating parameters of alternative resources may influence the system's performance with the changing levels of flexibility and operational control parameters such as scheduling rules. The results of simulation study shows that expected benefits may not be present when routing flexibility (RF) levels are increased with presence of the variations in physical and operating parameters. The increase in RF level

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becomes counterproductive under such environment when variations are above certain limits. It may be useful for decision maker to distinguish the level of flexibility up to which it can be gainfully increased under the presence of variations. Sarker et al. (1994) have presented a detailed classification for the types of manufacturing related flexibility as follows: routing flexibility (RF), machine, flexibility, process flexibility, expansion flexibility, job flexibility, design flexibility, material handling flexibility, setup time flexibility, and volume flexibility. Buitenhek et al. (2002) described that the design of these systems is an important issue of the expensive components of FMS. The design of FMS requires both the physical and the control aspects. Physical aspects includes the issues such as types and numbers of machines, material handling systems, processing times on a machine, machine setting time, tool changing time, transportation time, loading, unloading time, etc. and for the control aspects, the design involves defining the scheduling rules or algorithms that defines the way the system is to be operated. Gupta and Buzacott (1989) explained that the flexibility does not come from the abilities of machine alone; in fact flexibility is the result of a combination of factors like physical characteristics, operating decisions, information integration, and management practice.

3. Overview of flexible manufacturing system

There are three capabilities that a manufacturing system must possess in order to be flexible:

- The ability to identify and distinguish among different incoming part or product styles processed by the system.
- Quick changeover of operating instructions.
- Quick changeover of physical setup.
- To qualify as being flexible the automated system should pass these four tests:
- Part variety test.
- Schedule change test.
- Error recovery test.
- New part test.

The FMS has emerged as one of the revolutions in the manufacturing industries in recent years. It has made it possible to produce a variety of parts in less time and cost. The application of FMS in the current market scenario can satisfy the growing demands of variety, quantity and speed at the same time. The components of the FMS can be classified into two categories:

3.1 Hardware

Machine tools, handling systems, guided vehicles, inspection center, robots, etc.

3.2 Software

Software for FMS can further be classified into extrinsic and intrinsic functions.

The different levels of manufacturing flexibility can be defined as follows:

3.2.1 Basic flexibilities

- Machine flexibility: machine's ability to adapt to a variety of products.
- Material handling flexibility: it is a measure of the system's ability with which different part types can be transported and properly positioned at the various machine tools.
- Operation flexibility: it measures adaptability to alternative operation sequences for processing a part type.

4. System flexibilities

4.1 Volume flexibility

It measures system's capability to operate efficiently at different volumes of the part types.

4.2 Routing flexibility

It is the system's ability to use multiple machines to perform the same operation on a part. It is a measure of the alternative paths that a part can effectively follow through a system for a given process plan.

4.3 Process flexibility

It is a measure of the volume of the set of part types that a system can produce without changing any setup.

4.4 Product flexibility

The volume of the set of part types that can be manufactured in a system with minor setup.

4.5 Aggregate flexibilities

4.5.1 Program flexibility

The ability of a system to run for long periods.

4.5.2 Production flexibility

The volume of the set of part types that a system can produce without major investment in capital equipment.

4.5.3 Market flexibility

The ability of a system to efficiently adapt to changing market conditions.

The case study presented in the paper mainly consists of two kinds of flexibilities machine flexibility and routine flexibility. A key issue in the FMS is the performance evaluation of the system.

The better performance of the FMS results in reduced labor costs, increased output, decreased manufacturing costs, increased flexibility, and reduced production lead time. The major performance measures used in the study were machine utilization and overall productivity. Machine utilization increases as the jobs to be processed on the machine increases and a bottleneck machine has 100% utilization in the system. The machine utilization is measured by the number of hours it operates in the system to the total available hours in the system. The design and performance evaluation of the FMS system is a complex process and requires a thorough investigation. Three different methods have been proposed and compared in the presented case studies to evaluate the different cases of different FMS systems. The feasibility of the different techniques has also been reviewed in order to determine their successful application in the evaluation of FMS system.

5. Petri net

Petri nets are a class of modeling tools, which is well-defined mathematical foundation and easy to understand graphical feature. It is a powerful design tool which facilitates visual communication between people who are engaged in the design process. A Petri net is a directed graph consisting of three structural components – places, transitions, and arcs. Places which are drawn as circles represent possible states or conditions of the system while transition, which are shown by bars or boxes, describe events that may modify the system states. Manufacturing system is a discrete system. Hence any modeling has to be based on the concepts of events and activities. An event corresponds to a state change. When using Petri nets, events are associated with transitions. Activities are associated to the firing of transitions or/and to the marking of places. Queuing models can also be used for handling events and activities but synchronizations are difficult in these models. Hence Petri net is preferred. Analysis of the Petri net reveals important information about the structure and dynamic behavior of the modeled system. This information is used to evaluate the modeled system and suggest improvements of changes. Petri nets are used to model the occurrence of various events and activities in a system.

6. Modeling in Petri net

The system consists of loading and unloading station, two process stations, inspection center and two AVGs. To start a cycle, raw parts and the AVGs must be available. Then only firing will take place. The AVG carries a raw part from loading station to the process station according to the given sequence for the different parts. After the completion of an operation in one station the part is again carried by AVG to its next required station. At the end the part is carried to the unloading station. Place representing the stations have tokens according to the number of machines they have. The Petri net model is simulated to get the overall productivity of the given system.

7. System description for a case study

The system shown in the Fig. 1 consists of three robots, two machines, i.e. a drilling machine and a milling machine and an inspection center. The system also consists of two conveyors, conveyor in and conveyor out. The system has operational flexibility in the sense that two types of products are produced in the system using two different process operations. Type A product undergoes milling operation only whereas Type B product undergoes drilling and then milling. Both the parts are inspected before moving to conveyor out. Robot 2 loads the milling and drilling machine from conveyor in, and Robot 1 loads the part B onto the milling machine after it completes the drilling operation. It also unloads the milling machine. Robot 3 loads the inspection center. Material handling system consists of three robots, one conveyor and three work carriers with mean transport time =5 min (see Table 1)

8. Solution methodology

Three types of techniques are applied to find the parameters of the given FMS; the two are simulation techniques and the one is mathematical technique. The simulation technique is Petri net. The system is modeled in this.

8.1 System modeling

The network is shown below. The system is using different kinds of nodes such as create node, assign node, await node, free node, collect node, terminate node, goon node, etc. to describe the given system. The system starts with creating entities at an interval of 2 min. A goon node is used to divide in different sequence according to their operational requirements. In the await node, entities wait for the resources to be available. The system is using three resources of robots, one resource of milling machine and one resource of drilling machine each having a capacity of three. An inspection system is also present in the system. The system runs for 1 week working hours. The system consists of loading and unloading station, two process stations, inspection center and two AVGs.

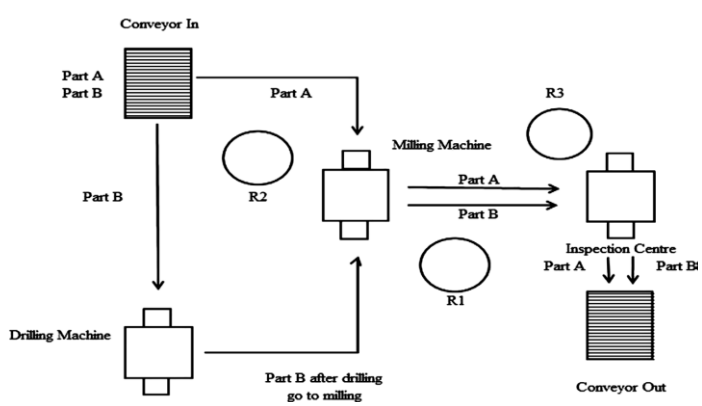

Figure 1: Block diagram of considered FMS in case study

9. Results and Discussions

The following operations and processes have been listed on different machining centers in Table-1.

Table 1: List of operations and process time on different machining centers

Part	Part mix	Operation	Process time (min)	No. of servers	Frequency
A	0.4	Load	4	1	1
		Mill	25	3	1
		lisped	6	1	1
		Unload	2	1	1
B	0.6	Load	4	1	1
		Drill	20	3	1
		Mill	30	3	1
		Inspect	8	1	1
		Unload	2	1	1

Table 2. List of operations and process time on different stations.

Part	Weekly demand	Process sequence	Load	Process station		Inspection station	Unload station
			A	B	C	D	A
1	250	A –> C –> D –> A	5		21	14	3
2	350	A –>B –> D –> A	5	22		14	3
3	150	A –> B –> C –> D –> A	5	20	22	15	3
4	250	A –> C –> B –> C –> D	5	15	20	14	3

To start a cycle, raw parts and the AVGs must be available. The AVG carries a raw part from loading station to the process station according to the given sequence for the different parts. After the completion of an operation in one station the part is again carried by AVG to its next required station. At the end the part is carried to the unloading station. The utilization and overall productivity is then compared .There are large numbers of techniques such as simulation techniques, modeling techniques, mathematical programming which can be used to evaluate the performance of any FMS

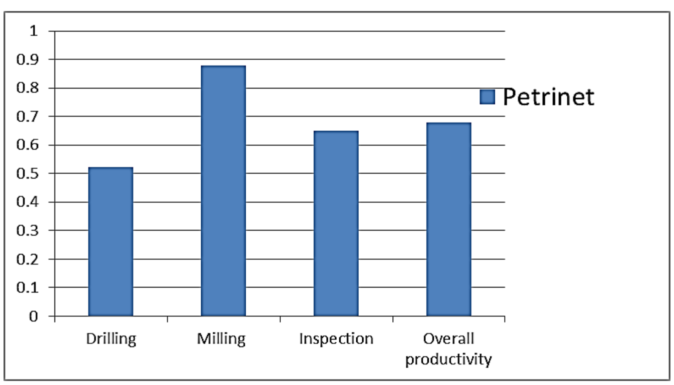

Figure 2: Comparison of utilization from different operations for case study

10. Conclusion

From the results it can be concluded that the performance obtained for a given system from the techniques is very clear and precise. Hence it can be said that these techniques are applicable to any FMS system to evaluate and confirms its performance.

References

[1] Browne, J., Dubois, D., Rathmill, K., Sethi, P., Steke, KE., 1984. Classification of flexible manufacturing systems. FMS Mag., 14–27.
[2] Bruccoleri, M., Sergio, NL.,Perrone, G., 2003. An object-oriented approach for flexible manufacturing controls systems analysis and design using the unified modeling language. Int. J. Flexible Manuf. Syst. 15 (3), 195–216.
[3] Buitenhek, R., Baynat, B., Dallery, Y., 2002. Production capacity of flexible manufacturing systems with fixed production ratios. Int. J. Flexible Manuf. Syst. 14 (3), 203–226.
[4] Chan, FTS., 2001. Effects of routing flexibility on a flexible manufacturing system. Int. J. Comput. Integrat. Manuf. 14 (5), 431–445.
[5] Chan, F.T.S., Bhagwat, R., Wadhwa, S., 2007. Flexibility performance: Taguchi's method study of physical system and operating control parameters of FMS. Rob. Comput. Integr. Manuf. 23, 25–37.
[6] Chen, S.C., Ke, Y.L., Wu, J.S., 2001. Coloured petri-nets approach for solving distribution system contingency. Proc. IEEE 148 (5), 463–470.
[7] Cheng, T.C.E., 1985. Simulation of flexible manufacturing system. Simulation 45 (6), 299–302.
[8] Chin-Jung, T., Li-Chen, F., Yung Jen, H., (1992). Modeling and simulation for flexible manufacturing system using Petri net. Second Int. Conf. Autom. Technol. 4, 31–36.
[9] Crockett, D., Dearochers, A., DiCesare, F., Ward, T. (1987). Implementation of a Petri net controller for machine workstations. Proc. of IEEE Robotics Automat. Conf. 1861–1867.
[10] Cuninghame, Green R.A., (1979). Minimax Algebra, Vol. 166 of Lecture Notes in Economics and Mathematical Systems. Springer- Verlag, Berlin, Germany. Delgadillo,
[11] G.M., Llano, S.B., 2006. Scheduling application using petri nets: a case study: intergra´ ficass.a.'. In: Proceedings of 19th international conference on production research, Valparaiso, Chile. Diaz, M., 1982. Modeling and analysis of communication and cooperation protocols using Petri net based models. Comput. Networks 6.

[12] Ezpeleta, S.D., Colom, J.M., Martinez, J.A., 1995. Petri net based deadlock prevention policy for flexible manufacturing systems. IEEE Trans. Rob. Autom. 11 (2), 173–184.

[13] Ge, S.S., Lee, T.H., Gu, D.L., Woon, L.C., 2000. A one stop solution in robotic control system design. IEEE Rob. Autom. Mag. 7, 42–55.

[14] Gertz, M. W., Khosla, P. K., (1994). Onika: A multilevel human– machine interface for real-time sensor-based robotics systems. In: Proceedings of SPACE 94: The Fourth International Conference and Expo. on Engineering Construction, Albuquerque. Gupta, D., Buzacott, JA. 1989. A framework for understanding flexibility of manufacturing systems. J. Manuf. Syst. 8 (2), 89–97.

[15] Gurel, A., Bogdan, S., Lewis, F.L., Huff, B., (2000). Matrix approach to deadlock-free dispatching in multi-class finite buffer flowlines. IEEE Trans. Autom. Control 45(11), 2086–2090.

[16] Huang, Y-M., Chen, J-N., Huang, T-C., Jeng, Y-L., Kuo, Y-H., 2008. Standardized course generation process using dynamic fuzzy petrinets. Expert Syst. Appl. 34, 72–86.

[17] Jain, S., Foley, W.J., (1986). Basis for development of a generic fms simulator. Proc. Second ORSA/TIMS Conf. Flexible Manuf. Syst.: Oper. Res. Models Appl., 393–403.

[18] Kalkunte, M.V., Sarin, S.C., Wilhelm, W.E., 1986. Flexible Manufacturing Systems: A Review of Modeling Approaches to Design, Justification and Operations. Flexible Manuf. Syst.: Methods Stud.. Springer, Berlin, pp. 3-25.

[19] Kimon, P.V., 1990. On the hierarchical modeling analysis and simulation of flexible manufacturing system with extended Petrinets. IEEE Trans. Syst. Manuf. Cybernatics 20 (1), 94–109.

[20] Kovacˇ ic, Z., Bogdan, S., Reichenbach, T., Smolic´-Rocˇak, N., Birgmajer, B., (2001). FlexMan – A computer-integrated tool for design and simulation of flexible manufacturing systems. In: Proceedings of the Ninth Mediterranean Conference on Control and Automation Control, Dubrovnik

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