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Manufacturing flexibility and their control for enhancing the performance of FMS: A Review

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Abstract:

It is an inherent capability of a manufacturing flexibility that refers to a production system to accommodate the environmental dynamic effects successfully and efficiently. The capacity of adoption of change makes a system as flexible. The system with computer-controlled machine tools and automated transportation and handling of parts under the control of an integrated computer may be called flexible manufacturing system. Flexibility in a system can be attained by providing an overall control that guides the functions of both the computer-controlled machine tools and the automated material handling systems. These systems are designed to be able to allow fast and economical changes in manufacturing processes, permitting quick response to changes and allowing customization in products. This work performs a comprehensive review of the controls of a flexible manufacturing system for enhancing its performance. Detailed conclusion on the literature of different control strategies used by the researchers is given in the last. Recommendation for future research is also provided.

Keywords: flexible manufacturing system (FMS), control strategies.

1. Introduction:

FMS is a computer controlled system that can produce a variety of parts or products in any order, with negligible tool setup changing time. The flexibility in manufacturing systems are generally reflected in different kind of flexibilities i.e. machine flexibility, sequencing flexibility, routing flexibility etc.

Machine Flexibility is the fundamental type of flexibility of a manufacturing system that caters the system to adopt change of product types, and also ability to change the operations

sequence. While routing flexibility enabled manufacturing system has an ability to explore multiple routes for the parts to perform the same operation using different machines. The best application of an FMS is found in the production systems for mid volume and mid variety.
FMS due to its inherent flexibility will take care of the part volume that operated at different operational conditions to give the desired output. The efforts for achieving best quality at lower cost with shorter response time always prevail in any competitive industry, that the manufacturing system becomes more complex with a large number of uncertainties. The decision-making at shop floor in such an uncertain environment in manufacturing system is divided into four stages i.e. design, planning, scheduling & control.

This work is carried out with the motive to explore different studies conducted on the impact of control strategies on the performance of an FMS.

2. Background:

Many of the researchers explore the manufacturing flexibility and its control strategies for enhancing the system performance in respect to the different types of flexibilities like machine flexibility, routing flexibility, sequencing flexibility etc. In this review we are trying to explore the effect of some control strategies on the flexible manufacturing system.

2.1 Flexibility

The word flexibility is largely used, but the concept of it still vague. Firstly in 1939 George Stigler introduced its concept Carlsson (1989). A flexible system can be defined as to accommodate customers' preference change. On the contrary, Sethi and Sethi (1990), Hyun and Ahn (1992) identify that it as a multi-dimensional concept in a manufacturing system that is either reactive or proactive in nature. The environmental uncertainty whether it is internal or external in the organization are reactive nature while proactive nature of flexibility deals market uncertainties or influence of the customers dynamic expectations Gerwin (1993). Therefore it is essential for the system designers or managers to have knowledge of flexibility type and their levels and also know what extent of flexibility is required to attain a certain level of performance.

2.2 Manufacturing Flexibility

Numerous manufacturing flexibilities have been yet reported in the literature. Cheng et al. (1997) states the three flexibility types like diversity flexibility that upkeeps the variety of product change, response flexibility to deal with the rate of change and volume flexibility that is associated with the change in magnitude. Sethi and Sethi (1990) added three more flexibilities in list provided by Browne et al. (1984) that are material handling, program and market flexibility. An extensive list of manufacturing flexibilities provided by Koste and Malhotra (1999) namely; machine, labor, material handling, routing, operation, expansion, volume, mix, new product, and modification flexibility. Braglia and Petroni (2000) observed that the manufacturing flexibility may be classified in different ways that are machine, routing, process, product, volume, expansion and layout flexibility.

Kumar and Sharma (2015) explored various manufacturing flexibility dimensions from the literature that is critical to flexible manufacturing system. The results of the study show that flexibility dimensions are very vital at shop floor level in a manufacturing plant in order to enhance the performance of a manufacturing system.

From the above review we observe that the different types of manufacturing flexibilities are addressed in the literature. Here the study concentrates on some fundamental flexibilities and their control strategies.

2.3. Machine flexibility

Wadhwa and Rao (2000), states that the flexibility of different manufacturing systems can be evaluated in a relative manner. One potential measure of the flexibility could be the set up change over time for different part types. According to Barad et al. (2003) machine flexibility is one of the fundamental flexibility in manufacturing system. The extent or level of machine flexibility can be measured as the set of different tasks that the machine is capable to perform. The response time for setup change can be measured in terms of the duration of its preparation tasks. That may include the time required to tool change, the tool positioning time, etc.

2.4. **Routing Flexibility**

According to Browne et al. (1984) routing flexibility is revealed as and when there is any break down of machines. Routing flexibility offers the decrease in lead-time and in last there is a fractional decrease in the total make span by using alternative routes. A mathematical model is developed to measures of routing flexibility and machine flexibility by Nagarur (1992). Wadhwa et al. (1998), shows that the makespan performance declines with decision delays incorporated by enhancing the routing flexible levels in a manufacturing system. A genetic algorithm is developed for the scheduling of FMSs with multiple routes Zhao et al. (2001). Barad et al. (2003), describes routing flexibility is the ability of system to process a part through variable routes. This will be only possible if every individual machine is capable to perform variable tasks with minimal set up change over time. Routing control decisions include selecting of routes that should be followed by the parts in the production system to maximize use of resources. Khan and Ali (2017) explored the effects of routing flexibility in different levels of sequencing rules, system capacity and system load conditions and finds out in all the conditions the maximum benefit of the routing flexibility can be achieved by incorporating second level of routing flexibility.

2.5. Sequencing Flexibility

There is a very few researchers explored unambiguously the simultaneous scheduling of jobs. Jaikumar and Solomon (1990) study a manufacturing system with primary objective is to enhance the resource utilization and minimizing the total travel time that results fleet size minimization. Polynomial time machine sequencing algorithm is proposed by them. Lacomme et al. (2005) addresses the scheduling problem in automated manufacturing environments. The problem is solved using a branch-and-bound discrete event simulation. A test is performed to investigate the system performance and makespan.

3. Flexible Manufacturing System

A Flexible Manufacturing System (FMS) is a highly automated system that manufactures parts Sethi (1990). One of the first approaches to the production-planning problem in FMSs has been proposed by Stecke (1981). Paulli (1985) addresses the scheduling problem by proposing a hierarchal algorithm based on the similarities with the job shop-scheduling problem. It minimizes the makespan of a set of jobs in an FMS in which operations can be performed by more than one machine. The role of flexibility can be viewed as one that provide the alternative decision solutions to certain discrete events, which the system should evolve. Wadhwa and Browne (1990) refer these events as decision points. Depending on the type of flexibility present in the manufacturing system, decision point provides opportunity for controlling the direction in which the system should evolve. Decision choices are typically exercised using control strategy, which manifest themselves as sequencing, dispatching and/or queue selection rules. Roy et al. (2001) proposes multi agent platform to take care of dynamic shop floor control problems in real-time. Sarma et al. (2002) develops a modeling framework that addresses the machine-loading problem of FMSs.

Venkata and Manukid (2008) proposed a methodology based on a combinatorial mathematics-based decision-making method for the evaluation of alternative flexible manufacturing systems. The methodology is developed to judge the relative merits of different flexible manufacturing systems for the industrial application considered. Several stochastic modeling methods have been applied to FMS reliability and performance. It is vital for take a look at the opposite side, particularly the effect these frameworks have on costing, item blends chose by the organization and the unavoidable compromise between creation rates and flexibility (Ali and Wadhwa 2015). The utilization of an FMS is found best in the creation of slight change in the arrangement of resources like those from a mass manufacturing. Decrease in assembly cost, Lowers the cost of every part created, Better work profitability, More machine effectiveness, Upgraded quality, Enhanced framework dependability, reduced lead time, in last Lowers the costs per unit (Shafiq et al 2017).

4. Experimentation Design

In this work some control strategies have been discussed in order to study the impact on

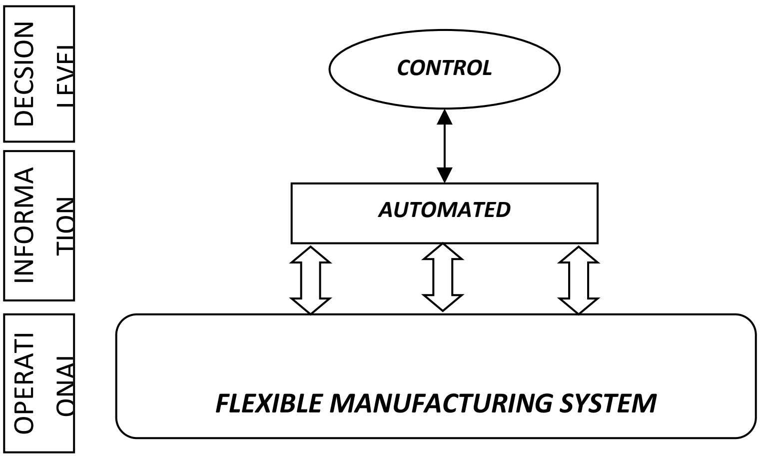

Figure: Conceptual framework

manufacturing flexibilities on control strategies at the operational level of flexible manufacturing system. Figure given below shows conceptual framework developed based on the GRAI model.

Wadhwa and Browne (1990) stressed on the proper control on flow of material that involve jobs flow, optimum recourse utilization and information system. The performance of the system is based on depth and nature of controls over the system. The present research work investigates the impact of these control decisions on the performance of FMS in

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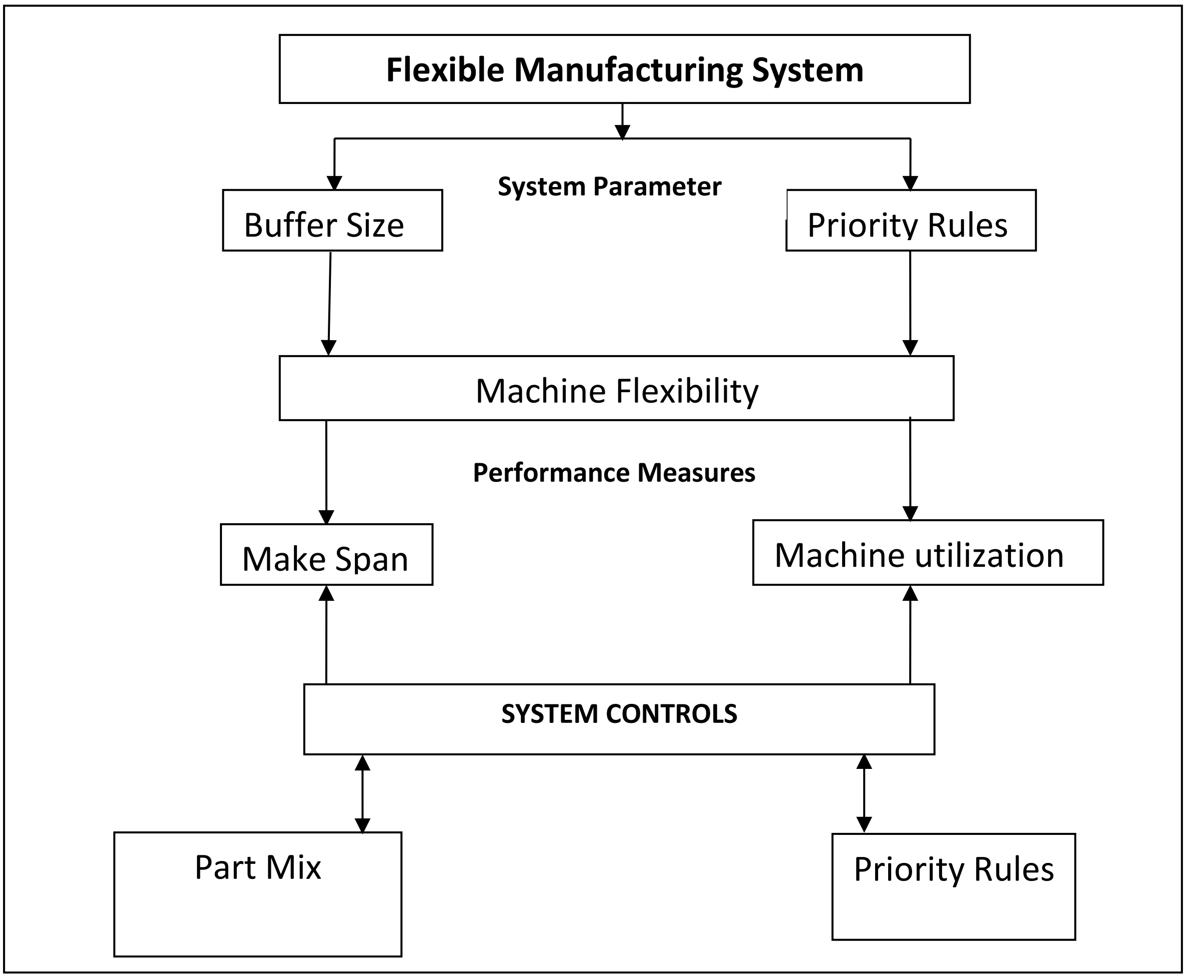
manufacturing flexibilities perspectives. The conceptual frame work of the control decisions along the FMS is shown in figure given below.



5. Conclusion

In the present study the conceptual model has been developed to show the integration of different components of an FMS and its control. The proposed manufacturing system consists of one of the fundamental machine flexibility with system parameters like buffer size and priority rules. System performance will be measured by using makespan and resource utilization as a performance measure. Three system control rules are considered in the given FMS that are Part mix, work order and priority rules.

From the literature much of the work has already been done on machine flexibility in the deterministic as well as stochastic environment, but yet some of the important corners are yet to be explored.

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