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Flexibility performance: Taguchi's method study of physical system and operating control parameters of FMS

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Abstract

In present manufacturing environment, the manufacturing flexibility has become one of the strategic competitive tools. Flexibility refers to the availability of alternative resources. These resources may have varied parameters, particularly related to physical and operating system. These 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. Is increase in a flexibility level provides desired improved performance output? If yes, than under what conditions of physical and operating parameters and under which control strategy (CS)? Is improved performance is present at all increasing levels of flexibility? Flexible manufacturing system (FMS) being consist of numerous physical and operating parameters and complex in nature, the solution to these questions can provide an understanding of the productive levels of flexibility for a given physical and operating parameters of an FMS. This paper establishes the need of modelling of the physical and operating parameters of flexible manufacturing system along with flexibility and presents a simulation study under Taguchi's method analysis of these parameters. The paper contributes an approach to study the impact of variations in physical and operating parameters of an FMS and to identify the level of these variations that do not restrict the advantages of flexibility. The results show that the expected benefits from increasing the levels of flexibility and a superior CS may not be achieved if the physical and operating parameters of alternative machines have variations. Taguchi's method analysis indicates that relative percentage contribution of variations in physical and operating parameters of alternative resources should be negligible or minimum in the performance of FMS. Their increasing relative contribution may restrict the advantages of flexibility. If these variations are higher than increase in flexibility level may be counter productive.

Keywords: Flexible manufacturing system; Flexibility levels; Physical and operating parameters; Control strategies; Taguchi's method

1. Introduction

Evolving manufacturing environment offers new pressures to be confronted by the manufacturing systems, such as customised product (increasing variety) with delivery on time along with underline traditional requirements of quality and competitive cost. The manufacturing environment is changing and is quite different to the needs of the mass production period. The era of *mass customization* is emerging, leading to a need to manufacture a changing product and volume mix effectively. A manufacturing environment of increasing variety in products inspired by the vast capabilities of flexible manufacturing system (FMS) is evolving. In this environment the focus is on manufacturing *flexibility* rather than the *system efficiencies*. Rajput and Bennett [1] emphasise the need of greater flexibility, shorter cycle times and reduced inventory levels for present manufacturing environment. According to Wadhwa and Browne [2], flexibility offers opportunities to the control on flow of entities (material, resources and information, etc.) in a desirable direction among the available alternatives. However, first it is important to know whether this change in flow of entities provides

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expected benefits. The FMSs which are considered to be efficient with increasing variety of products and time-based delivery performance measure, the flexibility present in the system provides this capability to become most suitable in this manufacturing environment.

The increasing and fast changing product variety along with flexibility in manufacturing system has dramatically increased the complexity of management, which requires more effective design, planning, scheduling and control of production systems. An important goal for any manufacturing enterprise which wants to successfully compete in this environment is one related to having flexibility in manufacturing. These systems are expected to have a high level of flexibility and retain their productivity also, in contrast to the case of job shops where productivity is often sacrificed with any increase in flexibility. The increase in flexibility provides the alternative resources/machines to do the same processing [3]. All these alternative machines cannot be equally capable to perform same operation. The physical and operating parameters like processing time, loading/unloading time, tool changing time, machine setting time, job transportation time, performance of control strategy (CS), etc. may get changed on the alternative machines due to built-in constraints as compared to original machine. It is important for decision-maker to know the behaviour of these physical and operating parameters with changing levels of flexibility to have productive utilization of flexibility. Are these physical and operating parameters influence the performance of flexibility? Then how these parameters restrict to fish out the advantages of flexibility? According to Wadhwa and Bhagwat [4] it is important to judiciously increase the levels of flexibility of manufacturing system. This paper attempts to underline such issues and presents an approach to study the relative percentage contributions of variations in physical and operating parameters and other factors in the performance of a given FMS using simulation under Taguchi's method. The approach also provides an insight to decision-maker on the performance behaviour of physical and operating parameters at different levels of flexibility. Taguchi's method provides an opportunity for robust analysis of parameters contributing in the performance of a given FMS at their various levels of operations. The parameters can be set at different values (levels) to study their effects.

The organisation of the paper is as follows. Section 2 presents the background and motivation for the study. Simulation modelling has been discussed in Section 3, while experimentation design under Taguchi's method analysis has been presented in Section 4. The results and discussions has been organised in Section 5. Finally, conclusions are presented in Section 6.

2. Background and motivation

According to Browne et al. [5], an FMS is an integrated computer-controlled system with automated material handling devices and CNC machine-tools, which can be used to simultaneously process a medium-sized volume of a variety of parts. The main distinguishing feature of an FMS from a traditional manufacturing system is the flexibility. The expediency of FMS is judged by its potential ability that can persist with the changes in manufacturing environment. This ability is usually compressed into the term 'flexibility' [6] or more comprehensively an ability to cope with the uncertainty of changes [7]. According to Gupta and Buzacott [8], 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. Flexibility is critical in providing the effectiveness to manufacturing system under different operating conditions. Since physical and operating parameters play a crucial role in realising the benefits of flexibility, it is important that these issues may be studied in relationship to flexibility. It is also important to know whether increase in any type of flexibility in a system is productive or not as per expectation. Is it productive, than under what conditions of physical and operating parameters? Buitenhik et al. [9] describe that since the components of an FMS are generally expensive; the design of these systems is an important issue. The design of FMSs pertains to both the physical and the control aspects. For the physical aspects, it deals with 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 and unloading time, etc. As for the control aspects, the design involves defining the scheduling rules or algorithms that defines the way the system is to be operated. When designing an FMS, one would ideally like to determine the optimal configuration (including both the physical and the operating aspects). According to Lenderink and Kals [10] in sequencing decision apart from selection of a part for next processing based on CS, the operator has to consider also the alternative process plans available by the virtue of flexibility. The process plan may vary with machine tools due to different physical and operating parameters. The authors presented a model for minimization of evaluation time for loading. This clearly indicates that presence of flexibility may even put variations in decision-making time and hence, in the performance.

Bennett et al. [11] identifies the factors crucial to the development of efficient flexible production systems, namely: effective integration of subsystems, development of appropriate controls and performance measures, compatibility between production system design and organization structure, and argues that the flexibility cannot be potentially exploited if its objectives are not defined and considered at design stage. According to Shin and Shon [12], large CIM systems consist of numerous physical facilities and operating parameters, which may require more elaborative designing. In our opinion, these physical and operating parameters should be properly considered in