A Review on Design Consideration for Reconfigurable Manufacturing System

Anurag Anand, Prakash Kumar

Production & Industrial Engineering Department, BIT Sindri, Dhanbad

anurag2k87@gmail.com, hod.pe@bitsindri.ac.in

Abstract

In the present paper a review of design methodologies for reconfigurable manufacturing systems, with focus on different combinations of interchangeable designs in alignment with symmetric and asymmetric combinations of the system are analyzed. With the different combinations of the crossover and without cross over it was concluded that machine reliability and gantry reliability of RMS with crossovers have higher degree of productivity. It can be said, that better the machine average reliability, larger is the solution of parallel line configuration or the vice versa. It can be concluded that in a larger system, the RMS has the higher capability than parallel line configurations.

Keywords: Reconfigurable Manufacturing System, Reliability, Productivity, Maintainability

1. INTRODUCTION

The invention of moving assembly line in 1913 was marked as the beginning of the mass production era. It has significant contribution towards the possibility for emergence of the dedicated machining line which further led to the development of advanced production for engines, transmission and main components of automobiles. The dedicated manufacturing lines provides the capability of high production rates for the specific part types which drastically enhanced production time as well as the entire cycle time of the product. Furthermore, NC and CNC systems were introduced which again acts as a revolutionary trend change in the entire manufacturing scenario of the world facilitating the entry of the flexible manufacturing system in the early 1980s [7]. Stecke and Solberg [16] who previously introduced operation policies of FMS, again developed the concept for the mathematical modeling for flexible systems easing the strategic goals of manufacturing enterprises were productivity, quality and flexibility in 1980s and 1990s. In the forthcoming era, the changing pace of the globalization and the increasing competitiveness in the manufacturing scenario FMS also found to be a partial solution for the economic prospects. Therefore, rising need for the rapid change in the production capabilities in response to the sudden market demands the concept for reconfigurable manufacturing systems are introduced [5]. In reconfigurable manufacturing system, the capability of scaling up and scaling down of the system structure both at software and hardware level in response to the sudden market changes makes it a very effective solution for the manufacturers leading to the proper cost effectiveness as well as the inventory control solution [6].

Characteristics of RMS : A typical Reconfigurable Manufacturing System has six characteristics as shown in fig 1 that includes Modularity, Integrative design features, Customized flexibility, Scalability, Convertibility, and Diagnosability [10]. Y.Koren applied these characteristics in the event of transformation of the entire manufacturing system as to some of the components such as controllers, system control software etc.

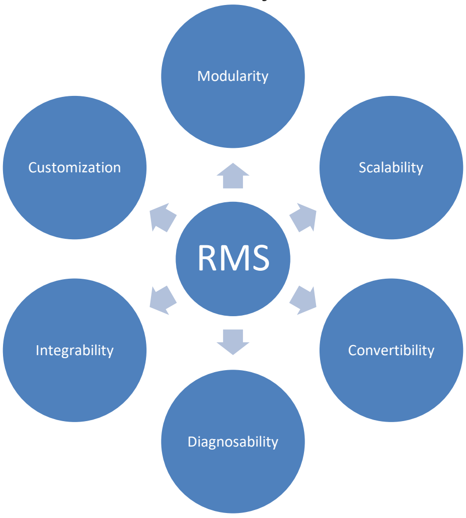


Figure 1. Characteristics of RMS

***Modularity**:* It is one of the most important characteristics of the reconfigurable manufacturing system responsible for the reduction of the complexity both at design and evaluation level of the system. The system includes many components that are typically modular in nature (e.g., machines, axes of motion, controls, and tooling) which are replaced or upgraded to a better version when found to be necessary suiting new applications.

***Scalability**:* It is defined as the ability to adjust the production capability of the system as per the needs with minimal cost, in minimal time, over a large capacity range, at given capacity increments. It can also be said as the ability to maintain cost effectiveness when there is a change of the market demands or workloads as shown in the fig 2 and fig 3.

***Convertibility**:* Convertibility can be defined as the ability to adjust production functionality that can be changed from one form to another. It includes the capability to switch over spindles of a machine as per the requirement of the system. Also, it can be adjusted manually with a passive degree of freedom for the production of different parts within a part family.

***Diagnosability**:* It is the capability to detect and diagnose the root cause of the problem for the output defects of the products which further can be corrected or adjusted quickly. However, diagnosability can be further categorized into delectability, predictability and distinguish-ability.

***Customization**:* It is defined as the ability to modify or design the system or machine capability to achieve a higher degree of flexibility. It significantly classifies the RMS and its enhanced superiority over the classical FMS /CNC system. The typical feature of the customization enables the designing of the system for the production of the entire part family irrespective of a particular part type.

Integrability: Integrability is the ability to integrate different modules quickly and very precisely with different sets of control interfaces as well as different mechanical and software information. It allows a typical system designer to relate different types of the parts and their features for the respective machines for corresponding operations to be performed which further leads to the product-process integration.

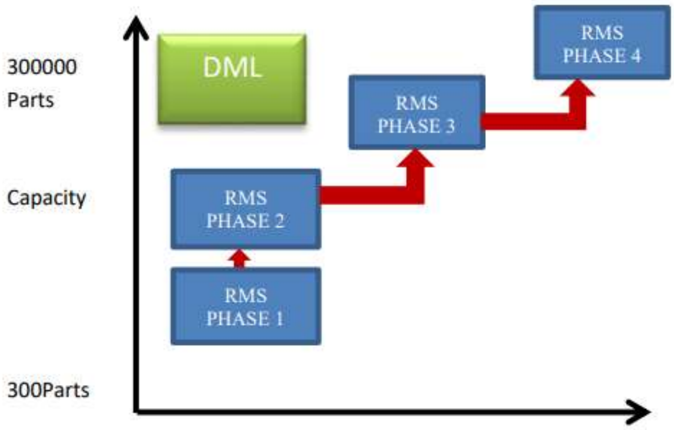


Figure 2. Both DML and FMS are static; RMS are dynamic, with capacity and functionality changing in response to market changes.

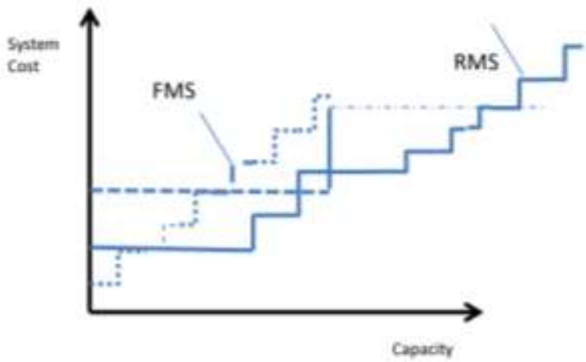


Figure 3. Manufacturing system cost versus capacity

2. Classification of Configuration

In order to classify the configurations, there should be known daily demands Q (parts/day) total machining time for the part, t (min/part), are given. In reality, machining times vary widely depending on the equipment involved, but here to begin, it was represented as:

$$N = \frac{Q*T}{\frac{Min}{Day}*Machine\ Reliablity}$$

Here, the system is to be assumed to be 100% reliable for all pieces of equipment, which therefore, represent the reliability = 1. If the number of machines is to be calculated it must be rounded to the next larger integer. For instance, if 300 parts per day are needed and the processing time for each part is 9.5 min, at least three machines are needed in the system assuming working time of 1000 min/day [12]. Generally, the total number of configurations for the machines are higher, therefore a logarithmic scale was considered which led to the increase of the configuration on a linear scale. Here, with the linear arrangement it was found that with the aforementioned number of machines, the possible configuration for the RMS is pretty much lower to meet the possible demands of the products.

No. of Machines	No. of Possible Configurations	No. of RMS Configurations
3	3	3
5	18	9
7	198	36

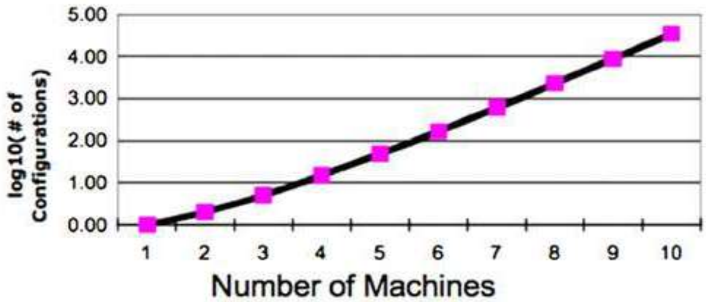


Figure 4. Total number of system configuration for different number of machines

Here, configurations are classified into symmetrical or asymmetrical which is further evaluated by its machine arrangement and connections. If a configuration a and b have almost identical arrangements but still, they are considered differently as connections among the machines—configuration b uses cross coupling between different stages. In the present system the symmetrical system has only 18 configurations for the 5 machines (fig.4) and will be considered as the symmetric configuration by the designer as shown in fig 5. However, asymmetric configurations add immense complexity and are not feasible in real manufacturing production lines. The different combinations led to a very higher possible configuration of the asymmetric configurations as compared to the symmetric configurations. It is only due to the different position as per the reconfiguration science as per their requirements.

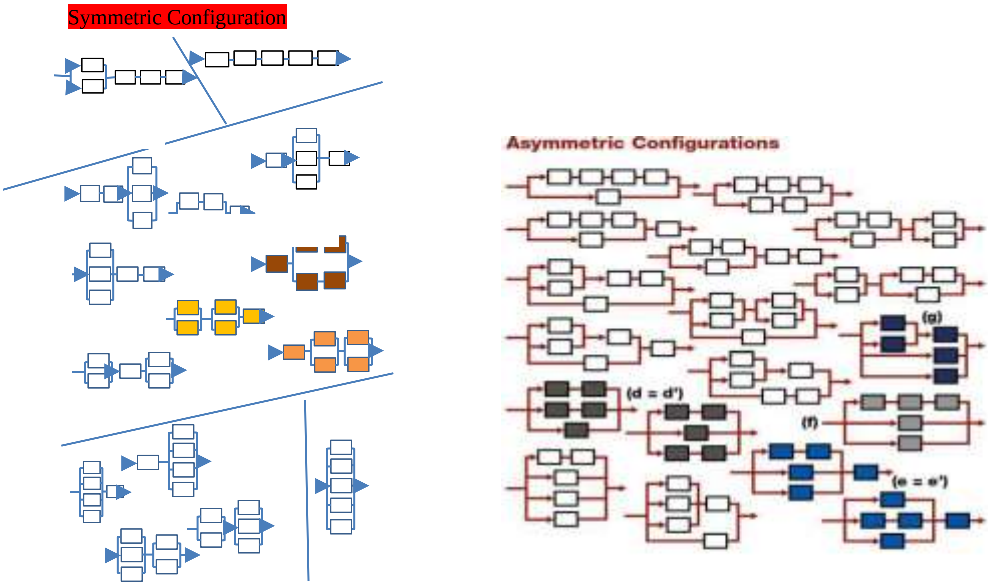


Figure 5. Configuration of five machines

The asymmetric configurations are usually not suitable for real time machining scenarios, which can be categorized into variable-process configurations and single-process configurations which are represented by the fig 6. below. With the non-identical flow paths variable configurations are characterized for the different parts [19]. For instance, the system depicted in fig. 6 below may have a number of possible flow-paths: a–b–c–d–e, g–c–f, g–c–d–e, etc. The execution of the plan depends on the chosen paths of the part to be processed in the system which is impractical as the designers will not go to the effort to design multiple process plans for the same part and different process plans and corresponding flow-paths increase part quality problems and make quality error detection more complicated.

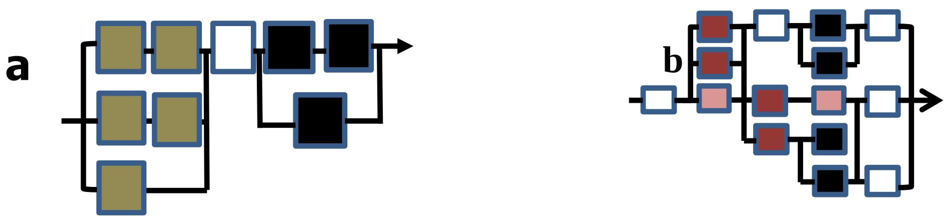
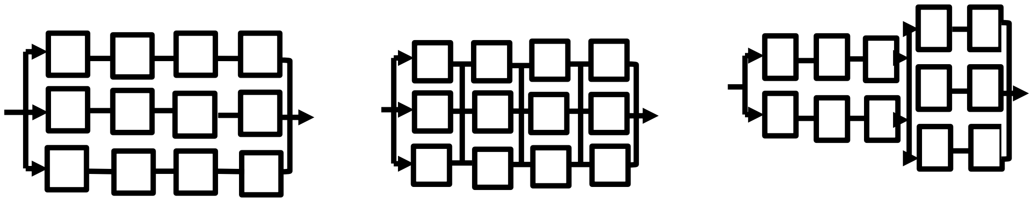


Figure 6. Two classes of asymmetric configuration



Class I

Series in Parallel = Cells Crossovers

Class II RMS

Configuration with Crossovers

Class III

No

Figure 7. Three classes of symmetric configuration

The processing time for the symmetric configuration in a particular stage is almost equal due to the mixing of different types of machines that perform exactly under the same sequence of the task. Here, system designers also no consider because of the excessive in competitiveness and impractical considerations [4]. It can be concluded from the above discussion that in real time machining scenario, only symmetric configurations would be considered which can be further classified into three stages [12]as shown in the above figure 7.

4. Conclusion

The RMS configuration has a spine gantry with reliability identical to that of the conveyors as shown in the fig 10. which attributes to calculate tradeoffs between cell-gantry reliability and machine reliability. In the above fig. 11 result plotted for gantry reliability (or availability) of Gr = 0.96, and machine reliability of Mr = 0.90[12]. As per the various research analysis borderline based on machine reliability and gantry reliability shows that RMS with crossovers have higher degree of productivity and hence, they are preferred. It can be said that the better the machine's average reliability, the larger the solution of parallel line configuration or vice versa. It can be concluded that in a larger system, the RMS has the higher capability than parallel line configurations. Secondly, with respect to higher machine reliability the cell configuration yields higher productivity. Although, the installation cost of the RMS is higher but with the changing market demand scenario, and the need of scaling up or down of the system RMS can easily cope up with the highly un-predictive boundaries.

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Biographies

Anurag Anand received the bachelor's degree in Mechanical Engineering from Ranchi University in 2010, the master's degree in Automated Manufacturing System from Birla Institute of Technology, Mesra, Ranchi in 2013, and currently pursuing philosophy of doctorate degree in Production and Industrial Engineering from BIT Sindri, respectively. He has interdisciplinary work experience both in the teaching as well as in the corporate sector handling the major projects. His research areas include reconfigurable manufacturing system, maintenance strategy, forecasting, fuzzy applications and soft computing analysis

Dr. Prakash Kumar received the bachelor's degree in Production Engineering from Birla Institute of Technology, Mesra, Ranchi in 1996, the master's degree in Production Technology from BIT Sindri in 2009, and the philosophy of doctorate degree in Production Engineering (Maintenance Management) from Vinoba Bhave University in 2017, respectively**.** He has over two decades of experience in technical education and is currently serving as a Professor and Head, Department of Production and Industrial Engineering, BIT Sindri, Dhanbad. He began his career in Tata Motors Ancillary industry and later moved on to Jojobera Power Plant and BIT Mesra. He is President of IIC (4.0). Also contributing significantly as an Expert Representative for Centre of Innovation, Incubation & Entrepreneurship (CIIE) of IIT(ISM) Dhanbad. His fields of interest are Maintenance Technology, Productivity Improvement through Lean Manufacturing, Expert System, Change Management and Industrial Management.