A Review on Design Consideration for Reconfigurable Manufacturing System

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Abstract

In the present paper, a review of design methodologies for reconfigurable manufacturing systems is discussed, with a 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 crossover 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 an extended degree of capability in comparison to parallel line combinations.

Keywords: Reconfigurable Manufacturing System, Reliability, Productivity, Maintainability

1. INTRODUCTION

The beginning of the mass production era marked in 1913 with the introduction of the moving assembly line. It has significant contribution towards the possibility of the emergence of the dedicated machining line (DML), which further led to the development of advanced production for engines, transmissions, and major components contributing towards the automotive sector. The introduction of DML provided 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 acted 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 the operation policies of FMS, again developed the concept for the mathematical modelling of flexible systems, easing the ideal objective of a manufacturer, that is flexibility, productivity and quality, to enhance the capability of the entire system 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 responsive acts towards 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 the system structure both at the software and hardware levels in response to sudden market changes makes it a very effective solution for the manufacturers leading to proper cost effectiveness as well as the inventory control solution [6].

2. 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 for different attributive components of the system.

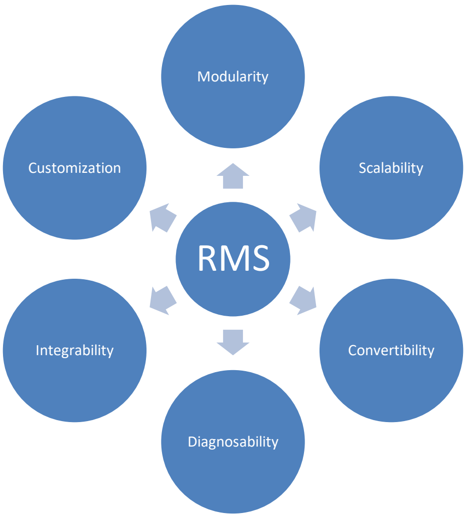


Figure 1. Characteristics of RMS

Modularity*:* It is the most important indicative component of the reconfigurable manufacturing system responsible for the reduction of complexity both at design and evaluation level of the system. The system includes different type of components that are typically commutable in nature which can be machines, axes of motion, controls, and tooling that can be replaced or upgraded to a better version when found to be necessary suiting new applications.

Scalability*:* It expresses the performance ability with adjustment of production capability of the system as per the needs with optimum cost consideration alongwith minimised time, over a large range of capacity within its capacitive increments. It can also be said as the ability to maintain cost effectiveness when there is a change in market demands or workloads as shown in the fig 2 and fig 3.

Convertibility*:* Convertibility explains the capability to adjust operational functionality that can be changed from one form to another. It includes the capability to switch over the spindles of a machine as per the requirements 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 find and optimise the basic cause of problems for 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 explains the capability of modifying or designing 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 provides feasible designing of the system for the operational output of the similar type of part, irrespective of a particular part type integration.

Integrability: It is the integrative capability of different modules in a very quick and accurate manner with different sets of interface controls as well as different mechanical and software information. It allows a typical system designer to relate various types of part type and their capability for respective machines for corresponding operations to be performed which further leads to the product-process integration.

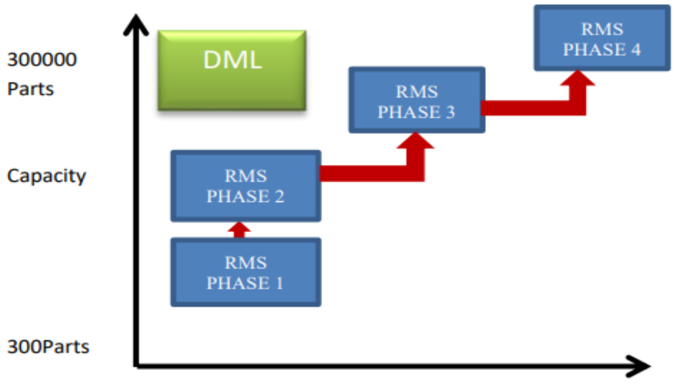


Figure 2. Static Nature of DML and FMS Vs Dynamic Nature of RMS

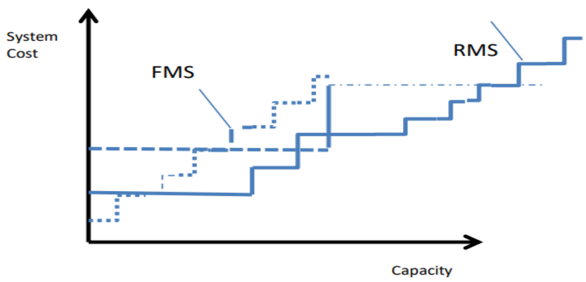


Figure 3. Comparison of Manufacturing System Cost and Capacity

3. Classification Of the Configurations

In order to classify the configurations, there should be known daily demands of part types per day (Q), total time required by part type (t) in minutes, are given. In real kind scenario, the equipment used attribute towards the machining time but in general here it is 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. To calculate the number of machines it can be rounded off the data towards the nearest higher side of the integer

On considering that, if 300 parts per day are needed and thereby the time required by each part type for processing is 9.5 min then minimum requirement of the machine time that are assumed to be in the work becomes 1000 min/day [12]. In general, the total number of combinations for the machines are higher, therefore a logarithmic scale was considered which led to the increase in 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 products.

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

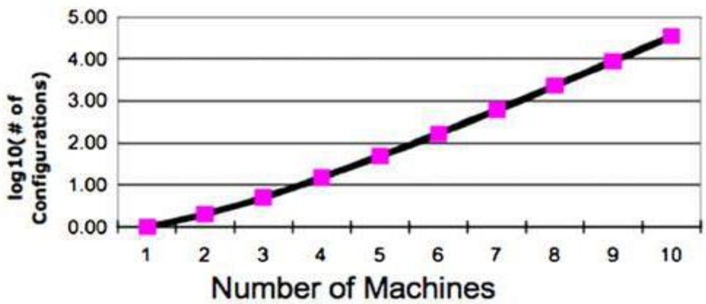


Figure 4. Representation of Total System Combination or Configuration on the Basis of Different Numbers of Machines

Here, different combinations are classified as symmetrical or asymmetrical, which is further evaluated by its typical arrangement of connections with respect to machines. For instance, if configurations have almost similar kind of arrangements, i.e they are identical, but they are considered differently because of cross coupling between different stages of machines, 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 combinations of configurations add very higher degree of complexity and are practically feasible in real-world kind operational lines. The different combinations led to a very higher possible configuration of the asymmetric configurations as compared to symmetric configurations. It is only due to the different position as per the reconfiguration science as per their requirements.

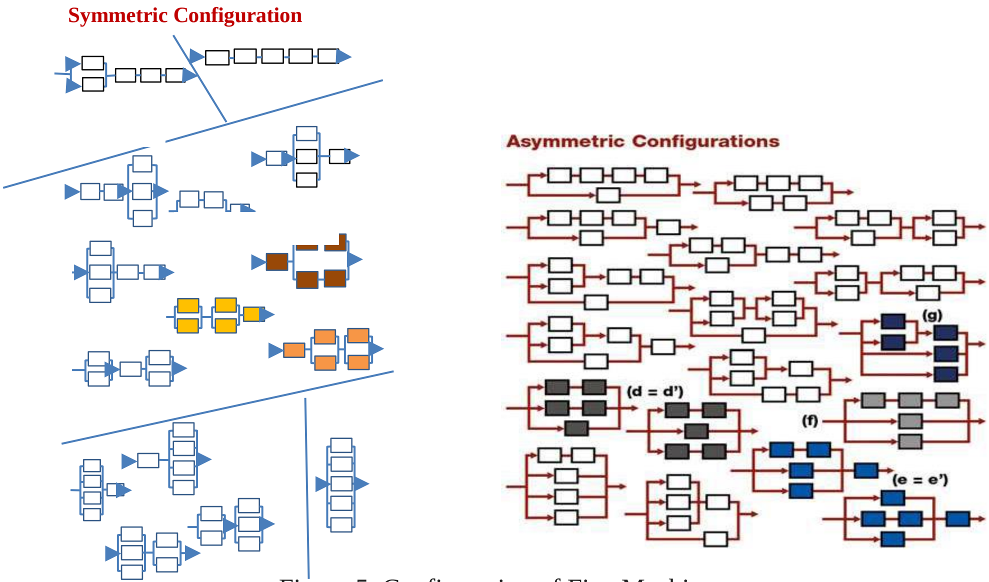


Figure 5. Configuration of Five Machines

In general, it was found that asymmetric configurations are typically not suitable for real time machining scenarios, which can be categorised into variable-process configurations and single-process configurations, which are represented by Fig. 6. below. With the non-identical flow paths, variable configurations are characterised for the different parts [19]. For instance, the aforesaid system shown in fig 6 can have different sequences of flow paths such as g–c–f-e, g–c–d–e, a–b–c–d–e, etc. It was not possible for a designer to design multiple prospective designs for the same part type with different corresponding flow paths. It is due the very higher possibility of the error in the part quality which are very tough in nature to be detected, which might led in the failure of the system.

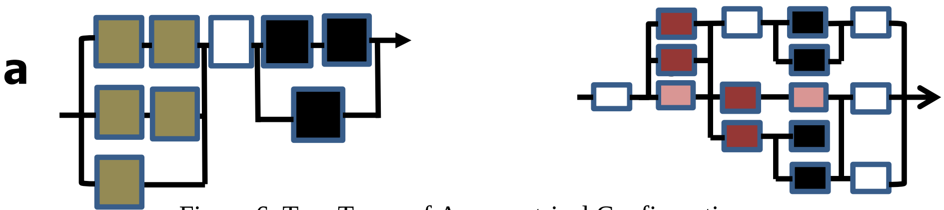
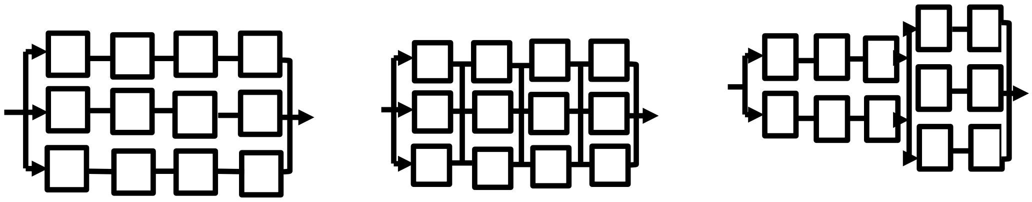


Figure 6. Two Types of Asymmetrical Configuration



Class I
Series in Parallel = Cells

Class II RMS
Configuration with Crossovers

Class III
No Crossovers

Figure 7. Three Types of Symmetrical Combination

The processing time for the symmetric configuration in a particular stage is almost equal due to the similarity in the sequence of operation that can be attributed to the different combinations of machine types. Here, system designers also not consider them because of excessive competitiveness and impractical considerations [4]. It can be said that practically only symmetric configurations are the only possible design consideration for the real time performance which is further classified into three stages [12] as shown in the above figure7.

4. CONCLUSION

The aforesaid configuration discussed represents that RMS has a spine gantry having identical reliability to that of the conveyors as shown in the fig 10. which further attributed towards the complex calculation of trade-offs between creditability of responsiveness(reliability) of cell gantry and hence the overall machine that is Gr = 0.96 and Mr = 0.96 respectively [12]. As per various research and analysis on the basis of machine and gantry reliability, respectively proven that RMS with crossovers have a higher degree of productivity and hence, they are preferred. It can be said that the better the machine's average reliability, there is higher extended 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 productivity of cell configuration becomes on the higher side. 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.

REFERENCES

[1] Cochran DS, Arinez JF, Duda JW, Linck J. A decomposition approach for manufacturing system design. Journal of Manufacturing Systems 2001–2002; 20(6):371–89.

[2] Dupont-Gatelmand C. A survey of flexible manufacturing systems. Journal of Manufacturing Systems 1981;1(1):1–16

[3] Freiheit T, Koren Y, Hu SJ. Productivity of parallel production lines with unreliable machines and material handling. IEEE Transactions on Automation Science and Engineering 2004;1(1):98–103.

[4] Freiheit T, Shpitalni M, Hu SJ. Productivity of paced parallel-serial manufacturing lines with and without crossover. Journal of Manufacturing Science and Engineering 2004;126(2):361–8.

[5] Koren Y, Ulsoy AG. Reconfigurable manufacturing systems. Engineering Research Center for Reconfigurable Machining Systems. ERC/RMS report #1. Ann Arbor; 1997.

[6] Koren Y. The global manufacturing revolution—product-process-business integration and reconfigurable systems. John Wiley & Sons; 2010.

[7] Koren Y. Computer control of manufacturing systems. McGraw-Hill; 1983.

[8] Lee HF, Stecke KE. An integrated design support method for flexible assembly systems. Journal of Manufacturing Systems 1996;15(1):13–32

[9] Koren Y, Kota S. Reconfigurable machine tools. US patent no. 5,943,750. August 1999

[10] Koren Y, Heisel U, Jovane F, Moriwaki T, Pritschow G, Ulsoy AG, et al. Reconfigurable manufacturing systems. CIRP Annals 1999;48(2):6–12.

[11] Koren Y, Ulsoy AG. Vision, principles and impact of reconfigurable manufacturing systems. Powertrain International 2002;14–21.

[12] Koren, Y., Shpitalni, M.: Design of reconfigurable manufacturing systems. Journal of Manufacturing system. 2011

[13] Koren Y, Ulsoy AG. Reconfigurable manufacturing system having a production capacity, method for designing same, and method for changing its production capacity. US patent no. 6,349,237. February 2002.

[14] Landers R, Min BK, Koren Y. Reconfigurable machine tools. CIRP Annals 2001; 49:269–74

[15] Pritschow G, Altintas Y, Jovane F, Koren Y, VanBrussel H, Weck M. Opencontroller architecture—past, present, and future. CIRP Annals 2001;50(2):463–70.

[16] Stecke KE, Solberg J. Loading and control policies for a flexible manufacturing system. International Journal of Production Research 1981;19(5):481–90.

[17] Son YK, Park CS. Economic measure of productivity, quality and flexibility in advanced manufacturing systems. Journal of Manufacturing Systems 1987; 6(3):193–207.

[18] Spicer P, Yip-Hoi D, Koren Y. Scalable reconfigurable equipment design principles. International Journal of Production Research 2005;43(22):4839–52.

[19] Spicer P, Koren Y, Shpitalni M. Design principles for machining system configurations. CIRP Annals 2002;51(1):276–80.

Biographies

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