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The Design of Adaptive Manufacturing Systems

Babak Beheshti
Assistant Prof. ,RSCOE, Pune, India

Abstract

This article provides a primer on Reconfigurable Manufacturing Systems, including its basic architecture and design ideas. It also describes the process of setting up an rms and suggests a way to determine the total number of configurations depending on the available machines. An important element of this work is a comparison between the rms configuration and the cell configuration. We have detailed the process of designing rms that exhibit all six essential qualities, including the incorporation of cutting-edge reconfigurable machine tools and reconfigurable inspection equipment. Modularity, Integrability, Customizability, Convertibility, Scalability, and Diagnosability are the Six Core Characteristics. Both of these guidelines increase efficiency and flexibility in businesses. An exact mathematical technique for creating rms is presented.

Configuration, Cell, Reconfigurable, Machine, Tool, Inspection, Reconfigurable, RMS,

I. Introduction

Manufacturers face several challenges in today's market, including demand fluctuations, the need to deliver a diverse variety of products, rapid advances in product and process technology, decreased product development times, and increased quality standards. While dedicated production lines (DPLs) and other traditional production methods may create similar things in large quantities, they lack the adaptability of a Flexible Manufacturing System. A reconfigurable manufacturing system may have its production capacity (the amount of product produced in a given amount of time) and functionality (the number of various sorts of components) adjusted on the fly. RMS Systems were designed for use in situations where quick reaction time and high levels of productivity are equally important. RMS products are very flexible and may be modified to suit the requirements of any given customer. Therefore, each RMS system is adapted to produce a certain product. Manufacturing resources in RMS may be added or removed to change production capacity. RMS was created to provide rapid replies at a low cost.to market changes, including changes in product demand, and to changes in the product itself continuous production in the face of machine failures Every productive machining job begins with RMS's main CNC machines, re-configurable machine tools, and re-configurable inspection equipment.

Classification of Configurations The classification of configurations requires thedetermination of the number of possible

configurations. The minimum number of machines, N needed in the system is calculated by the following equation.

product variety. On the other side, Flexible Manufacturing System is capable of giving product variety but as compared to DMLs its productivity is very low. Besides FMS is inca

pable of giving volume $N = ^{Q}$

Q = daily demand (parts/day)

t = total machining time for the part (min/part)(1)

flexibility and also the cost is high. ReconfigurableManufacturing System is a manufacturing SystemMaximum calculations assume 100% reliability i. e.machine reliability = 1.

First, configurations are classified as symmetricalconfiguration and asymmetrical configuration.

Symmetrical configuration is the configuration in which a symmetric axis can be drawn. Asymmetricalconfiguration is the configuration in which symmetric axis cannot be drawn. A configuration is then evaluated by its machine arrangement and connections. The type of material handling system determines the connections of a configuration. For example, configurations **a** and **b** have identicalmachine arrangements (one in stage 1, two in stage2and two in

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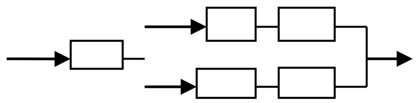
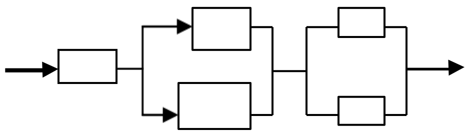
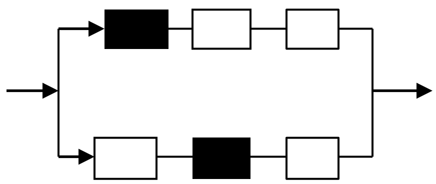


stage 3), but they differ because of different connections among the machines.

Configuration- a

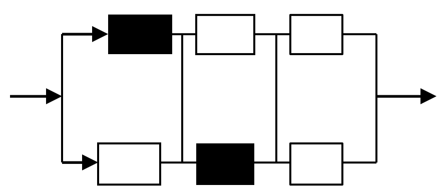


Configuration b uses cross coupling between stages 2and 3.
Symmetric configurations may be further dividedinto following three classes.
Class I – These are the configurations consisting of several serial manufacturing lines arranged in parallelwith no crossovers and known as cell configurations.



Configuration – b

The above figure shows symmetric configuration ofclass I. If the two black marked machines fail, the system production stops.
Class II – These are the configurations with crossover connections after every stage and known asRMS configurations. A part from any machine in stage (i) can be transferred to any machine in stage (i+1).



The above figure shows symmetric configuration ofclass II. If the two black marked machines fail, the system production may not be 100% but will not stop.
Class III – These configurations are the configurations in which there are some stages with nocrossovers.
Asymmetric configurations are complex and study ofasymmetric configurations is beyond this paper.

II. Comparison between RMS configuration andCell configuration

The comparison between RMS and Cell configurations is based on the following four factors. **Capital Investment - Both** the configurations have similar machine arrangements but different connections between the machines. The part handlingsystem is simpler and smaller in cell configuration ascompared to RMS configuration. Thus capital investment in RMS configuration is much higher.
Line Balancing - To be perfectly balanced, the processing time in all stages of the cell configurationmust be exactly equal. But to achieve a balanced RMS configuration only the following relation needsto be satisfied

$t_{s1}/N_{s1} = t_{s2}/N_{s2} = t_{si}/N_{si}$
(2)

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where N_{si} is the number of machines in stage i and $t_{si}$is the processing time per machine in stage i. Thus line balancing in RMS configuration is much better than cell configuration.

System scalability – RMS configurations are farmore scalable than cell configurations.

Productivity – Though machine reliability is low dueto crossovers at each stage, an RMS configuration offers higher productivity than that of a cell configuration.

Calculation of No. of RMS configurations In [1], the authors present a mathematical strategy that may be simply implemented by engineers when developing systems for flexible production. As we have shown, it is straightforward to determine from Eq. (1) the minimal number of machines N that should be used in the system. Here are the fundamental formulas for determining the total number of RMS configurations. To determine how many RMS configurations may be achieved with N machines in up to m stages, we use the formula:
Each cell in the Pascal triangle has a numerical value, which may be found by using the following formula. The value for N machines in m stages = (the value for N-1 machines in m-1 stages) plus (the value for N-1 machines in m) is the formula for determining the numerical value that corresponds to N machines grouped in m stages.

Taking the figure's Pascal triangle as an example, the total of the outputs of the two and three-stage machines with N equal to N1 = 5 yields 10.

Using the triangle, the designer may swiftly

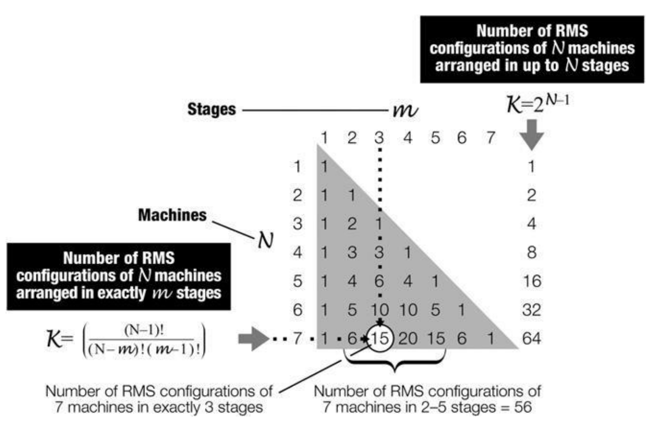
see how many different ways RMS may be set up

K = $\sum_{m=1} \binom{N-1}{m-1} = 2^{N-1}$ (3)for **N** machines arranged in **m** stages. For example,there are 15 RMS configurations when 7 machines

K, the number of possible configurations with **N** machines arranged in exactly **m** stages is calculatedby:are allowed to be arranged in exactly 3 stages. In addition, the Pascal triangle allows the designer to immediately calculate the number of possible RMSconfigurations for **N** machines arranged between *i*

$= \frac{(N-1)!}{(N-m)!(m-1)!}$ (4)stages and *j* stages (*i*, *j* < **N**).

For example, for **N** = 7 machines arranged in up to 7stages, Eq. (3) yields **K** = 64 configurations, and if arranged in exactly 3 stages, Eq. (4) yields **K** = 15 RMS configurations. The mathematical results of these two equations for any **N** and **m** may be arranged in a triangular format, known as a Pascal triangle, shown in the following figure.



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Conclusion

The new system has to be built from the ground up to be easily reconfigured. To do this, the system and its devices are built with modularity in mind. System-level, machine-level, and control-software-level modifications may be made to the framework. This flexible design makes it easier to adapt systems and machinery to meet evolving market needs. With the specialized adaptability needed to produce all members of this component family, the production system should be developed in tandem with the part family.

References

[1] Journal of Manufacturing Systems (2011), by Y. Koren and M. Shpitalni, "Design of Reconfigurable Manufacturing System."

[2] he number of alternative configurations of a system was calculated [2] by Zhu, X. W. in 2005. ERC/RMS Tech.rep.