Efficiency assessment of Reconfigurable Manufacturing Systems

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Abstract

A novel Data Envelopment Analysis (DEA) approach is proposed to assess the technical efficiency of Reconfigurable Manufacturing Systems (RMS) by benchmarking the observed time allocation of the different system configurations and the inputs consumed and output produced in each of them. The inputs considered are the time usage of the different RMS modules, labour and energy consumed. The outputs are the number of units produced of each part type. The proposed approach is illustrated on a simulated dataset. The results show that the proposed approach can identify and quantify inefficiencies in the system operation, thus helping to increase productivity.

1. Introduction

Short lead times, more variants, low and fluctuating volumes, and low prices are some of the critical requirements that must be met by next generation manufacturing systems [1]. Strategies designed to meet these requirements lead to different types of manufacturing system, such as Dedicated Manufacturing Lines (DML),

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Flexible Manufacturing Systems (FMS) or, more recently, Reconfigurable Manufacturing Systems (RMS). DML include some dedicated machines producing a very low variety of products with high volume in a stable market but are unable to operate effectively in the present dynamic market scenario. FMS use expensive Computer numerical control (CNC) machines, programmable logic control, robotics, automated guided vehicles and automated storage and retrieval systems with fixed hardware and software to produce a variety of parts, but the implementation of these systems has not been very successful due to high cost of production and long cycle time since machines are general purpose ([2]). RMS concept emerged to yield, to the extent possible, both the changeable functionality of FMS and the scalable capacity of DML.

RMS is “a manufacturing system designed at the outset for rapid changes in structure, as well as in hardware and software components in order to quickly adjust production capacity and functionality within a part family in response to sudden changes in market or in regulatory requirements” ([2]). In RMS the system and its machines are designed for adjustable structures that enable scalability in both capacity and functionality. These manufacturing systems are configured around a product family with the customized flexibility required to produce all given extended product family ([3]). In other words, the manufacturing system must be able to yield different batch sizes of different product types, using the exact capacity and functionality required in each case.

RMS consist in multiple Reconfigurable Machine Tools (RMT), Modular Reconfigurable Machine Tools (MRMT) and/or CNC machines, load/unload stations, automatic material handlings and automated storage systems. Each CNC machine within a Reconfigurable Machine Cell (RMC) has an automatic tool changer and a tool magazine with limited capacity. The automatic tool changer gives flexibility to the CNC machine so that it can perform various types of operations without requiring a great effort in switching from one operation to another. In contrast to CNC machines, RMT is designed for a specific, customized range of operation requirements and may be cost-effectively converted when the requirements change ([4]). RMT has an adjustable and modular structure that enables either machine scalability or machine convertibility, using some basic and auxiliary machine modules ([5], pp. 211-218). The basic modules are structural in nature (such as base, columns, slideways and tables) and auxiliary modules are kinematical or motion-giving (such as spindles, tool changers, etc). A particular combination of different basic and auxiliary modules provides a particular set of operational capabilities for the new RMT configuration. In an MRMT, the modularity and flexibility of the machine is achieved by adding and removing the modules, selected from precompiled modules and concatenated by means of a series of standardized mechanical interfaces, thus permitting a variety of combinations in which modules could be joined ([6]). Fig. 1 shows a typical RMS configuration with CNC, RMT and MRM.

![Fig. 1. Typical RMS configuration with CNC, RMT and MRMT](image)

In order to assess the efficiency of an RMS Data Envelopment Analysis (DEA) can be used. DEA is a well-known methodology for assessing the relative efficiency of a number of similar processing units, commonly labelled...
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