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Responsiveness of Reconfigurable Manufacturing System (RMS) Scheduling Decision to System Performance

A.A. Faieza, A.M. Nawawi, S.R. Hamzeh, M.W. Rohidatun and S.A. Ahmad

Universiti Putra Malaysia, Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, 43400 UPM Serdang, Selangor.

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ABSTRACT

Background: This paper reviews a research or study on responsiveness of scheduling decision to system performance of reconfigurable manufacturing system (RMS). Many researchers around the globe had intensively looking forward for this kind of manufacturing system over the flexible manufacturing system (FMS) due to the flexibility in capacity and functionality. This paper focuses the method on performance measurement on RMS scheduling. The combination of both scheduling and system performance approaches were translated into a mathematical model for better and more precise analysis. The application of artificial intelligence (AI) in a system modeling indicates the serious intention of industries on RMS application.

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INTRODUCTION

By quick evolvement in manufacturing technology, Flexible manufacturing system (FMS) looks capable of accommodating the product variety but in comparison to DML the productivity is low (Mehrabi, M.G., K. Ulsoy, 2000). The high cost becomes a major constraint among the manufacturers in order to implement this kind of manufacturing system (Mehrabi, M.G., 2002). By having the advantages of both capacity and functionality adjustment in order to cope up with high variety of products and production volume makes RMS very applicable as a new type of manufacturing system (ElMaraghy, H.A., 2006). In Reconfigurable Manufacturing System (RMS), it is consist of equipment with modular structures for customized flexibility so that it can be easily reconfigure the whole system accordingly to produce a family of product in a different level of production volumes. The configuration of the system has a significant impact on performance of the RMS production output and quality (Koren, Y. and A.G. Ulsoy, 1997).

Other publications such as (ElMaraghy, H.A., 2006; Aguilar, A., 2013) has discuss on various method of making capacity decision for RMSs. The issues have been look forwarded for capacity decision such as selection of equipment, multipart production and stochastic demand. Some publications have focus on modularity of Reconfigurable Machine Tool (RMT) which is the core components of RMS. The RMT are developed as a type tools system by having different set of modules (Koren, Y., 1999; Koren, Y., 2005; Goyal, K.K., 2011). It is consist of several basic and auxiliary modules such as the base and the slide ways while the spindle heads and the tool changer are for auxiliary modules by having quick and easiest changeover in a minimum steps (Koren, Y., 1998; Youssef, A.M.A., H.A. ElMaraghy, 2007; Youssef, A.M.A., H.A. ElMaraghy, 2006).

Necessity of the System Performance:

The system components reconfiguration over the time for a multi set of individual product range that always in small volume capacity and in a very short delivery lead time. This situation requires a mapping of the manufacturing system capabilities and other characteristics by developing a proper performance measure. In order to measure the performance of RMS system, many characteristics need to be considered such as modularity, convertibility, scalability and diagnosability (Gumasta, K., 2011). There are many study has been carried out over the years on RMS modeling, most of the researchers were focus on the cost reduction and reconfiguration effort in their RMS model. Some addressed on the handling varies functionality and capacity demand over the planning and scheduling. In the other way, most of the researchers have similarly figure out the

Corresponding Author: A.A. Faieza, Universiti Putra Malaysia, Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, 43400 UPM Serdang, Selangor.

problems into two phases. For the first phase, solution for each stage is recorded based on cost criterion. Then, for a second phase, the best solutions for each time zone recorded from the previous phase is chosen based on the objective of minimization reconfiguration required at various stages (ElMaraghy, H.A., A.M. Deif, 2006).

This new manufacturing paradigm, called Reconfigurable Manufacturing System (RMS) is created for rapid adjustment of production capacity and functionality in response to new market and process requirements which promises customized flexibility in a short time (Koren, Y., 1999). The application of RMS can be widely increased if it is designed for multiple configurations, where individual configuration combinations in order to form the products. The use of common units to create product variants can be described as configuration. By this configuration, the significant reduction of the number of different parts to be manufactured for a product family while adequate variety is achieved by combination of different configuration as shown in figure 1. From this figure there are two configurations of Reconfigurable Machine Tools A and two configuration of Reconfigurable Machine Tools B and one configuration of Reconfigurable Machine Tools C. For performing an operation at each stage from A to C.

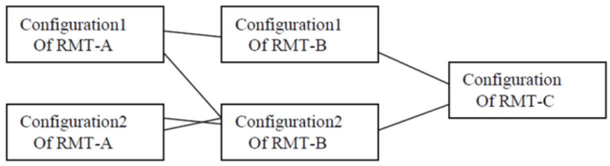

Fig. 1: Machine configuration at different stages (Kamal, K.M., K.J. Pramod, 2013).

Performance Measure:

The generic functions of manufacturing performance measures helps to study the current state of manufacturing situation, monitor and control of operational efficiency, to drive the improvement program and to gauge the effectiveness of manufacturing decisions. Since, the modern manufacturing challenge is to have a responsive manufacturing system and Reconfigurable Manufacturing System is a step forward in this direction. This system is characterized as being responsive, whose production capacity and functionality can be adjusted as and when required. Since RMSs are still in a very nascent stage thus it becomes important to investigate and highlight some of the performance issues so that practical implementation of such system may get realized.

Reconfigurable manufacturing system (RMS) is able to adjust production capability and functionality by adding system equipment or changing system configuration. System productivity and flexibility are influenced by system configuration, currently, how to evaluate the performance of hybrid series-parallel and hybrid parallel-series configuration, and develop a configuration model to meet the requirement of RMS, is still an open issue.

Based on the research (Kamal, K.M., K.J. Pramod, 2013), the selection of a feasible machine configuration for performing an operation is based upon four parameters:

a) Cost; b) Reliability; c) Utilization; d) Quality:

The cost depicts the economy of the feasible alternative, while the reliability, utilization and quality represent the responsiveness. In the following section, four main performance indices are proposed for finding the overall suitability of a feasible alternative machine configuration.

a) Cost (C):

The configuration cost at various stage is calculated using

$$C = n \times C_m \qquad (1)$$

Where n = D/p

n is no of machines required to satisfy the demand (D)

p is the production rate of machine

C_m is the cost of machine

The cost is a non-beneficial attribute and is to be minimized.

b) Reliability (R):

It is the probability of a product performing its intended function for a stated period of time under certain specified conditions. Reliability is predicated on "intended function:" Generally, this is taken to mean operation without failure. However, even if no individual part of the system fails, but the system as a whole does not do what was intended, then it is still charged against the system reliability. The system requirements specification is the criterion against which reliability is measured. If we are using single machine in each stage for each configuration then the reliability is given by

$$R_{series} = \prod_{i=1}^{n} R_i \qquad (2)$$

And if the no of machines at each configuration are more than one then the reliability is given by

$$R_{parallel} = 1 - \prod_{i=1}^{n} (1 - R_i) \qquad (3)$$

Where R_i is the reliability of the i th configuration reliability is a beneficial attribute and is to be maximized.

c) Utilization (U):

The definition of utilization is the ratio between the actual output of firms to the maximum that could be produced per unit of time, with existing plant and equipment. Obviously, "output" could be measured in physical units or in market values, but normally it is measured in market values. It can also be defined as the ratio of actual processing time to the total production time. Utilization is a beneficial attribute and is to be maximized.

d) Quality (Q):

Quality can be defined as the conformity to requirements. Quality means the responsiveness of the system. A system is highly responsive if its reliability and utility is high. So the quality can be the average of utilization and reliability.

$$Q = \frac{R+U}{2} \quad (4)$$

Dynamic Scheduling:

Some papers figure out the limitations of the static approaches to scheduling in the presence of real-time information and present a number of issues that have come up in recent years on dynamic scheduling or planning (Fuqing, Z., 2012). They define the issues or problems in dynamic scheduling and provide a detail review of the state-of-the-art of recently developed research on dynamic scheduling. The principles of several dynamic scheduling techniques, namely, heuristics, meta-heuristics, multi-agent systems, and other artificial intelligence techniques were described in detail, followed by a discussion and comparison of their potential. Based on the comparative study, it is shows that a Multi-Agent System (MAS) was very promising approach of current and future research in dynamic scheduling. While component-based software technology enables modular reconfigurable software architecture for control systems, agent-based technologies brings reconfigurability into logic of control systems since agents can be added or replaced freely in agent-based systems. An agent is a computer program which has a capability of autonomous action in order to meet design objectives or requirement. A Multi-Agent System (MAS) is a system composed of a population of autonomous agents, which cooperate with each other to reach common objectives, while simultaneously each agent pursues individual objectives.

Some researchers studied the weaknesses of agent-based systems and suggest to apply it's with cautions (Deshmukh, T.M., 1999). A centralized control system based on global information and optimization techniques are highly likely to yield better decisions than completely agent-based system. It is usually impossible for agent-based systems to find a global optimization point and therefore a system performance was unpredictable (Brussel, H.V., 1999; Duffie, N.A., R.S. Piper, 1987; Diep, D., J. Reaidy, 2004). Global properties of such systems emerge from all individual behaviors and direct individual interactions. Global performance is therefore unpredictable, and generally simulation is used to prove or establish stable, good performing agent-based solutions. Another potential problem is the effects of large number of agents and excessive communications (Shen, W., 2002; Wang, C., 2003). It will significantly worsen the system performances. Due to these issues, agents can be designed to be activated only when exceptions occur. Compared to a pure agent-based scheduling system, such exception handling mechanism avoids the risk of missing the global optimal point and reduce system burden when system is under normal condition. Uncertainty and the interruptions in production associated with the resulting agitations have been discussed as early as the beginning of 1900s (Aytug, H., 2005).

System Modeling:

With the rapid change in manufacturing market requirements, a reconfigurable manufacturing systems (RMS) with the feature of reconfigurability, have to be developed in order to cope with this unpredictable manufacturing situation. The performance of various scheduling strategies has been studied comprising multiple parts with some dependent and non-dependent operation sequences. The simulated model is based on the processing sequences of the jobs, processing times and inters arrival times. The different dispatching rules modeled are first come first serve, last come first serve, shortest processing time, longest processing time. The performance of scheduling measures has been studied in terms of the average value added time, waiting time, number in, accumulated time, number waiting and instantaneous utilization of resource and total number detained (Faisal, H., 2014). The study was presented a numerical model to demonstrate the simulation based approach using ARENA towards modeling of scheduling strategies.

There is some other study propose a genetic algorithm based methodology for responsiveness of scheduling measurement (Pavel, A.B., 2013; Imad, C., 2013). The method is based on the optimal selection of multiple performances parameters which includes minimizing the production cycle time and maximizing the operational capability of the production line. As a result of the study, they demonstrate the approach with the help of a numerical method illustration. In some other side, a generic model is proposed based on a decomposition of RMS along two axes (Zeeshan, S., 2015). The structure and configuration were detailed along two axes and discussed the logical and physical parts which are linked by operations. RMS is represented in a modular manner using SysML application. According to the paper, they applied those developments to an assembly process system.

As a result, the model developed was successfully implemented on the RMS. The generic model can also be deployed on other assembly systems that is regularly requires a quick and effective reconfiguration. Near the future, they recommended the approach to be integrated into a global process to design a comprehensive RMS system.

Recently, one researcher was presented a model of RMS by application of colored timed object-oriented which is based on the main difference between configurations of RMS and FMS, a modular hierarchical structure of RMS is developed (Xiuli, M., 2010). By the object-oriented method, all the object classes in the RMS model are identified. A macro-place is used to model the aggregation of many processes and a macro-transition is used to link all the related macro-places. Macro-places and macro-transitions are connected with arcs to form a Petri net named a macro-level so that the control logic of RMS. The example of Petri net model system level is shown in figure 2.

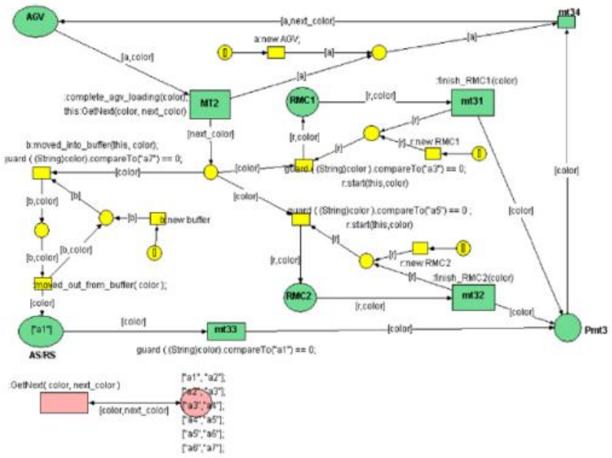

Fig. 2: System level Petri net model of RMS (Xiuli, M., 2010).

The macro-level Petri net is refined by ordered steps, each step describing these macro-places by more detailed sub macro-places until all the macro-places cannot be divided. As a result, the RMS activities can be compressed and modularized by the proposed method, so that RMS can be easily constructed and investigated by the system developers.

Conclusion:

The multi-agent based system was widely applied in dynamic scheduling of RMS. While the genetic algorithm (GA) offers the best solution in order to simulate the generic models of the RMS system's responsiveness scheduling. In future the authors plan to develop some artificial intelligence type of generic models in order to find the rapid response of dynamic scheduling in RMS system. The performance parameter may be studied for varying demand rate. This research gives a baseline for future research on quantifying re-configurability of reconfigurable manufacturing systems. Effects of material handling devices, tools, fixtures, etc. can also be considered in the process of finding the re-configurability of the system. Furthermore, work can be done on sensitivity of the re-configurability.

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