SOME PERFORMANCE ISSUES IN RECONFIGURABLE MANUFACTURING SYSTEM

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Abstract: The new manufacturing system paradigm, Reconfigurable Manufacturing System (RMS), that uses Reconfigurable Machine Tools (RMT) as its main components, has been designed to provide the exact capacity and functionality as per need by just reconfiguring RMTs using modular components in hardware and open architecture in control. It has the ability to provide cost effective and reasonable substitute to manufacturing industries which are facing highly unpredictable and frequently changing market scenario driven by global competition. The paper reveals important aspects related to RMS research since its inception. Keeping in view, the fierce market competition there is need to address the performance issues in RMS and facilitate successful implementation of RMS in an industry. Performance issues are the areas of RMS research requiring more focus.

Index Terms: Manufacturing Responsiveness, Operations and production management, Performance Issues, RMS

I. INTRODUCTION

In this fast changing global competitive era, customers demand latest and highly customized products with ever-shortening life cycles, high quality and low cost. Global Competition is now faster than never before and continuously growing further at a higher pace. To survive in the present global market scenario, industries are forced to compete in product variety as well as in cost and thus replacing older products constantly with the latest versions (Galan et al., 2007). The social, economic and technological changes have given birth to a new objective: Manufacturing Responsiveness, i.e. the ability of a production system to respond to disturbances which impact upon production goals and consequently, its ability to adapt to changing market conditions (Elmaraghy et al., 2004). The manufacturing industry cannot stay competitive and survive in today's global market without proper adaptation to the fast changes. This in turn requires restructuring and re-planning of manufacturing systems more frequently and within shorter lead-time. It has motivated the manufacturers/ researchers all over the world to investigate better ways of manufacturing. RMS has been designed in such a way to provide the exact functionality and capacity at the right time (Koren et al., 1999). Thus it can be changed as and when required to be a dedicated system or a flexible system or in between. Therefore, RMS will not be more expensive than FMS or even DMS (Mehrabi et al., 2000; Mehrabi et al., 2002). An RMS is supposed to provide the advantages of FMS economically and with more responsiveness. In fact the RMS paradigm is an attempt to avoid the limitations of all of the previous manufacturing philosophies (Kumar, 2010) and to sum up their advantages. Further, going beyond the objectives of all previous manufacturing paradigms, it also permits reduction of lead time for launching new systems, reconfiguring existing systems and rapid modification and quick integration of new technology and/or new functions into existing systems (Koren et al., 1999; Mehrabi et al., 2000; Mehrabi et al., 2002). All these advantages of RMS may enable an SME to face the challenges imposed on it by the prevailing manufacturing environment. An RMS facilitates an SME to adjust itself economically to the changing requirements, as and when required.

A literature review of previous works (He and Kusiak, 1998; Koren et al., 1999; Mehrabi et al., 2000; Mehrabi et al., 2002; Kumar et al., 2010 etc.) reveals that RMS achieves high responsiveness to market turbulences because of its distinctive features discussed below:

- It is created by incorporating basic process modules, both hardware and software, that will be rearranged quickly and reliably.
- It provides customized flexibility for a particular part/part family and is open ended, so that it can be improved, upgraded, and reconfigured, rather than replaced to accommodate future products and changes in market environments.
- It allows adding, removing, or modifying specific process capabilities, controls, and software or machine structure to adjust production capacity and to provide the customized functionalities in response to changing markets demands or technologies.

These features are acquired by an RMS because of several inherent design characteristics of its all components such as modularity, integrability, customization, convertibility, scalability, diagnosability and mobility.

II. NEED OF RECONFIGURATION

The traditional choices of manufacturing system as discussed earlier do not adequately address the current market needs as they were planned for definite product and volume for adequately large period. Therefore, current manufacturing environment has some significant requirements for a manufacturing system such as shorter lead time, variable volume and low cost. Common reasons for reconfiguration; changes in product mix (may include introduction of a new product), changes in product design, changes in product volume, changes in raw materials, changes in process and technology (Webster and Tyberghein, 1980; Savsar, 1991), shorter product life cycles, higher product variety, increasingly unpredictable demand, shorter delivery times (Benjaafar and Sheikhzadeh, 2000), and so on. Recent trends in the industry suggest that existing configurations do not meet the needs of multiproduct enterprises and also there is need for a new generation of manufacturing systems that should be flexible, modular, and easy to reconfigure. Flexibility, modularity, and reconfigurability could save industries and there is need to redesign their current manufacturing systems each time their production requirements change. Reconfiguration process can be highly expensive and disruptive, especially when the entire factory has to be shut down and production stopped. For industries which function in volatile environments, shutting down every time as soon as new product is launched or demand varies is simply not a sensible option. Most industries, ranging from big to small, encountered mounting frustration with the existing manufacturing system choices. This is particularly smaller in industries which always launch and offer an ample range of products with variable demand. Such industries need to have manufacturing system which can either used for extensive range of products or be easily reconfigured accordingly.

The traditional choices of manufacturing systems; such as dedicated, cellular and flexible manufacturing systems do not sufficiently address the mentioned requirements as these are designed for specific product and definite volume for a somewhat longer period (e.g. 3-5 years) (Lahmar, and Benjaafar, 2000). The design criterion used in traditional manufacturing systems is a measure of long-term material handling efficiency which is unable to confine the right of way of the flexible factory. As a result, manufacturing systems performance tends to deteriorate significantly with fluctuation in product volumes, mix, or routings (Lahmar, and Benjaafar, 2000).

Hence, there is a need for a new class of manufacturing systems that provide more functionality and capacity as per the requirement and explicitly accounts for flexibility and responsiveness.

III. NEED OF PERFORMANCE ISSUES IN RMS

Performance measures are very critical for firms to understand the present state of the manufacturing environment and to acquire suitable actions for maintaining firm's competitiveness in the market (Faisal Hasan et al. 2014). The common functions of manufacturing performance measures help 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 systems should be a responsive manufacturing system and Reconfigurable Manufacturing System is the most significant paradigm in the modern era. At the beginning, the authors have not considered any of the performance measures as discussed in the above sections. From the imagination of RMS to till date; it has been observed that cost has been taken the most important performance measure. Cost has been incorporated with other performance parameters like machine reconfigurability, operational capability (Goyal et al. 2012, 13) for RMS modeling. Ease of reconfiguration in terms of reconfiguration smoothness has been proposed by (Elamraghy, 2006). (Abdi et al 2003) have taken cost along with the quality as their performance parameters and in another work (Abdi et al 2004), the authors have considered capacity, functionality to calculate the reconfiguration time. In recent times, the focus of the fellow researchers has shifted to other issues like cycle time (Hasan et al.,2014), lead time (Puik, 2015), makespan (Azab 2015) and reconfiguration effort (Goyal et al. 2012), (Hasan et al., 2017) which have become the important performance measures to propose the efficient model for machine level configuration.

3.1 Cost

According to (Hon, 2005), the cost is of utmost concern for evaluation of performance of manufacturing system though its degree of comprehensiveness is very low. One of the initial efforts to capture reconfiguration costs in RMS was carried out by (Son et al., 2001) who similarity based reconfiguration RMS models. Later, (Elamarghy, 2007) the authors have presented a related reconfiguration cost model for assessing reconfiguration smoothness. In (Elamarghy, 2007), the authors proposed a cost model which combines both the physical capacity cost based on capacity size and costs associated with the reconfiguration path comprised of both penalty and effort cost related to scalability. The cost model given by (Spicer et al., 2007) comprehends labour costs, lost capacity costs, and investment/salvage costs due to system reconfiguration and ramp up.

3.2. Throughput

Throughput refers to the number of units or parts that leaves the manufacturing system upon completion of all the desired operations over some specified period of time. The performance of manufacturing system may be evaluated either taking throughput alone as an objective or it may be used in combination with other performance variables like cost, quality and reliability etc. as a multi objective performance evaluation problem. In (Tang, 2005), the authors introduced an approach for designing multi part reconfigurable product line based on the minimal ratio of cost to throughput as the criterion for the fitness evaluation while deciding upon the configuration and task allocations. The authors further used the same objective function of cost to throughput ratio to prove that, for the same number of machines, the multiple parts reconfigurable manufacturing system (MPRMS) comes out to be more efficient and economical than the traditional single-part manufacturing system.

3.3 Reliability and Availability

The reliability of the system is defined as the probability that a system performs without failure up to some specified period of time. The contribution of reliability of a station to a multi station system is dependent on the configuration. Therefore, reliability analysis is considered to be an important performance issue and an essential part of configuration design. Determining the reliability of any complex systems like that of a manufacturing system is not an easy task because of large number of interlinked components within it. The approaches generally applied for system reliability modelling and estimation are based on either simple part count, combinatorial approaches such as Reliability Block Diagrams (RBD) and Fault Tree Analysis (FTA) and state space Markov analysis.

3.4 Scalability

In RMS, scalability is defined as the system's adaptability to changes in production capacity through its reconfiguration. The concept of scalability in RMSs came into existence when reconfigurable machines were invented. Such machines have modular structure that can be quickly reconfigured to achieve increased capacity and adaptability to a variety of product designs. The authors in (Spicer, 2007), introduced the basic idea of scalable machines by designing RMTs which provides the option of adding or removing spindles to manipulate the capacity. For RMS, station paralleling within a stage as one of the possible approach towards scalability was proposed by Son et al., 2001.

3.*5 Ramp-up*

Koren et al. (1999) defined ramp up as "the time duration it takes for a newly introduced or just reconfigured production system to reach sustainable, long term levels of production, in terms of throughput and part quality, considering the impact of equipment and labour on productivity". Also, ramp up can be defined as "the period during which a manufacturing process makes the transition from zero to full scale production at targeted levels of cost and quality". The ability to minimize the ramp-up time for production especially when new customized variety in products are to be introduced has become a critical performance issue for many manufacturing companies.

3.6 Reconfiguration Effort (RE)

Different researchers have used different terms to indicate the meaning inherent in RE. Youssef et al. (2009) have defined the term 'reconfiguration smoothness' that represents easiness of transforming the system. Kumar (2010) have proposed 'reconfiguration index' to reduce the effort required to configure the system by classifying the reconfiguration tasks into six categories. Gumasta et al. (2010) formulated RI at the system level considering various RMS features. Goyal et al. (2013) have formulated 'responsiveness' by normalising operational capability, machine reconfigurability and cost. Hasan et al. (2014a) have proposed to 'reconfiguration effort' which is considered as inversely proportional to performance term 'service level' which was earlier defined by Xiaobo et al. (2000). Mittal et al. (2017) have proposed 'cumulative reconfigurability index' considering both the system and machine level configuration.

IV. CONCLUDING REMARKS

From the emergence of RMS to till date; it has been observed that cost has been taken as the most important performance issue. Cost has been incorporated with other performance issues like machine reconfigurability, operational capability for RMS modeling (Goyal *et al.* 2011 and 2013). Though ample of literature exists on the issues concerning RMS but the wide review of the literature revealed that still there is wide scope of study in almost all the areas of RMS. The literature reviewed gives an overview regarding the present and future arena of research on RMS. There is a serious need to address the performance issues and develop more insight into practical aspects of these systems. The central theme of any RMS design revolves around the performance issues that are addressed in the above sections and these issues help to develop strategies based on artificial intelligence and machine vision to facilitate RMS implementation. Many performance issues like Resource and Lead Time, material handling cost, Idle time, Maintenance & operating Cost, Reconfiguration Time and Reconfiguration Effort need to be addressed in future studies.

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REFERENCES

[1] Abdi, M. R. and Labib, A. W. (2003), "A design strategy for reconfigurable manufacturing systems using analytical hierarchical process (AHP): a case study", International Journal of Production Research, Vol.41 No.10, pp. 2273-2299.

[2] Abdi, M. R. and Labib, A. W. (2004), "Feasibility study of the tactical design justification for reconfigurable manufacturing systems using the fuzzy analytical hierarchical process", International Journal of Production Research, Vol. 42 No.15, pp. 3055-3076.

[3] Azab, A, ElMaraghy, H., Nyhuis, P., Frauenhofer, J.P., and Schmidt, M., (2013) "Mechanics of change: A framework to reconfigure manufacturing systems", CIRP Journal of Manufacturing Science and Technology, Vol. 6 No. 2, pp. 110-119.

[4] Benjaafar, S. Heragu, S.S and Irani, S.A. (2002), "Next generation factory layouts: research challenges and recent progress", Interfaces, Vol. 32 No. 6, pp.58-76.

[5] ElMaraghy, H. A. (2005),"Flexible and reconfigurable manufacturing systems paradigms" International Journal of Flexible Manufacturing Systems, Vol. 17 No. 4, pp. 261-276.

[6] Galan, R., Racero, J., Eguia, I., and Garcia, J.M. (2007),"A systematic approach for product families formation in reconfigurable manufacturing systems", Robotics and Computer-Integrated Manufacturing, Vol. 23 No.5, pp.489-502.

[7] Goyal, K. K., Jain, P.K. and Jain, M. (2012), "Operation sequence based similarity coefficient for rms", Annals of DAAAM and in the Proceedings of the 23rd International DAAAM Symposium Vienna, Austria, Vol.23, pp. 281-284.

[8] Goyal, K. K., Jain, P.K. and Jain, M. (2013), "A comprehensive approach to operation sequence similarity based part family formation in the reconfigurable manufacturing system", International Journal of Production Research, Vol. 51 No.6, pp. 1772-1776.

[9] Goyal, K. K., Jain, P.K. and Jain, M. (2013b),"A novel methodology to measure the responsiveness of RMTs in reconfigurable manufacturing system", Journal of Manufacturing Systems, Vol. 32 No.4, pp.724-730.

[10] Hasan, F., Jain, P. K. and Kumar, D. (2013b),"Optimum configuration selection in reconfigurable manufacturing system involving multiple part families", Opsearch, Vol. 51 No.2, pp.297-311.

[11] Hasan, F., Jain, P. K. and Kumar, D. (2014),"Performance issues in reconfigurable manufacturing systems", DAAAM International Scientific Book, Chapter 24, B. Katalinic (Ed.), pp.295-310.

[12] He, D. W. and Kusiak, A. (1977),"Design of assembly system for modular products", IEEE Transactions on Robotics and Automation, Vol. 13 No.5, pp. 646-655.

[13] Hon, (2005), Performance and Evaluation ff Manufacturing Systems, CIRP Annals-Manufacturing Technology, Vol. 54, No. 2, pp. 139-154.

[14] Koren, Y. and Ulsoy, G.A. (1999), "Creating the new manufacturing paradigm exactly the functionality and capacity needed, exactly when needed", available at: https://www.nsf.gov/pubs/2000/nsf00137/nsf00137l.htm (accessed 13 May, 2016).

[15] Kumar, R. (2010), "Comprehensive design strategy for a reconfigurable manufacturing system", PhD Dissertation, IIT Roorkee, India.

[16] Kumar, R., Jain, P. K. and Mehta, N. K. (2010), "A framework for simultaneous recognition of part families and operation groups for driving a reconfigurable manufacturing system", Advances in Production Engineering and Management, Vol. 5 No.1, pp. 45-58.

[17] Lahmar, M. and Benjaafar, S. (2002),"Design of dynamic distributed layouts", IIE Annual Conference Proceedings Institute of Industrial and Systems Engineers, USA, pp. 1.

[18] Mehrabi, M. G., Ulsoy, A. G. and Koren, Y. (2000), "Reconfigurable manufacturing systems: Key to future manufacturing", Journal of Intelligent Manufacturing, Vol.11 No.4, pp. 403-419.

[19] Mehrabi, M. G., Ulsoy, A. G. and Koren, Y. and Heytler, P. (2002),"Trends and perspectives in flexible and reconfigurable manufacturing systems", Journal of Intelligent Manufacturing, Vol.13 No. 2, pp.135-146.

[20] Mittal, K.K., Kumar, D., Jain P.K. (2017), "Configuration selection in reconfigurable manufacturing system based on reconfigurability", International Journal of Logistics Systems and Management, Vol. 27 No. 3, 363-379.

[21] Puik, E., Telgen, D., Van, M. L. and Ceglarek, D. (2017),"Assessment of reconfiguration schemes for reconfigurable Manufacturing Systems based on resources and lead time", Robotics and Computer Integrated Manufacturing, Vol. 43, pp.30-38.

[22] Savsar, M. (1991),"Flexible facility layout by simulation", Computers and Industrial Engineering, Vol. 20 No. 1, pp.155-165.

[23] Son, S. Y., Olsen, T. L. and Derek, Y. (2001),"An approach to scalability and line balancing for RMS", Integrated Manufacturing Systems, Vol. 12 No.7, pp. 500-511.

[24] Spicer, P. and Carlo, H. J. (2007),"Integrating reconfiguration cost into the design of multi-period scalable reconfigurable manufacturing systems", Journal of Manufacturing Science and Engineering, Vol. 129 No.1, pp.202-210.

[25] Tang, Y. and Qiu, R. G. (2004),"Integrated design approach for virtual production line based reconfigurable manufacturing systems", International Journal of Production Research, Vol. 42 No.18, pp. 3803-3822.

[26] Webster, D. B. and Tyberghein, M. B. (1980),"Measuring flexibility of job-shop layouts", International Journal of Production Research, Vol. 18, No.1, pp.21-29.

[27] Youssef, A. M. and ElMaraghy, H. A., (2007), "Optimal configuration selection for reconfigurable manufacturing systems", The International Journal of Advanced Manufacturing Technology, Vol.67, pp. 67-106.

[28] Xiaobo, Z., Jiancai, W and Zhenbi, L. (2000a), "A stochastic model of a reconfigurable manufacturing system Part 1: A framework", International Journal of Production Research, Vol. 38, No. 10, pp.2273-2285.

[29] Xiaobo, Z., Jiancai, W and Zhenbi, L. (2000b), "A stochastic model of a reconfigurable manufacturing system Part 2: Optimal configurations", International Journal of Production Research, Vol. 38, No.12, pp.2829-2842.