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Reconfigurable Manufaturing Systems (RMSs): *A* literrature review on the use of genetic algorithms for RMSs

Fatima Zahra Torki, Laid Kahloul, [1]Saber Benharzallah and Leila Belaiche

LINFI Laboratory, Computer Science Department, Biskra University, Algeria

[1]LINFI Laboratory, Computer Science Department, Batna 2 University, Algeria

***Abstract*—in the 21st century, Manufacturing Systems (MSs) will face serious challenges. To stay competitive, to survive in the current context and to fulfill the unpredictable and frequent market changes driven by global competition represent some of these challenges. This paper deals with the new concept of manufacturing systems which address these challenges known as Reconfigurable Manufacturing Systems (RMS). RMSs launched firstly in 1999 at University of Michigan, have been widely studied in many scientific publications with or without industrial applications. The objective of the current paper is to make an overview highlighting the core characteristics of RMSs, presenting a comparison between different manufacturing system paradigms and finally illustrating the use of genetic algorithms in RMSs optimization.**

Keywords*—reconfigurable manufacturing system; reconfigurability; genetic algorithm; RMT; DMS; FMS

I. INTRODUCTION

Nowadays the manufacturing environments have experienced a shift and are facing a numerous challenges and changes. Thus the market is completely changing and the products have to be customizable, varied and inexpensive to seduce the customers. Hence, competition has become global with the arrival of very competitive and highly responsive emerging countries [1]. Therefore, rapidly changing markets are becoming more frequent and under global competition and the demand for increasingly individualized products with shortened life cycles [2]. Therefore, Production has entered into an era where all manufacturing companies had to face competition in a global economy. This global competition increases the purchasing power of customers, which in turn leads to the frequent introduction of new products due to large demand fluctuations. To stay competitive, manufacturing companies had to adapt and use tools that not only made it possible to produce products with high productivity, but also to react effectively and economically to changes in the market and the needs of their customers.

These challenges have leaded and contributed to taking a step forward in the development of new generation of manufacturing systems. This new manufacturing systems can be themselves upgradeable, quickly reacting to market change and customer demand (responsiveness i.e., quick adaptation to market variations), and allowing to process technology and new functions to be rapidly and easily integrated. One of the most ambitious solutions to satisfy the above requirements are "Reconfigurable Manufacturing Systems" (RMSs) [4].

RMSs have emerged to meet these challenges with the aim of overcoming the disadvantages of traditional manufacturing systems, such that: the flexible manufacturing systems (FMSs) and the Dedicated Machine Lines (DMLs). DMLs provide a high throughput but are inapt to cope with high dynamic markets. However, even FMSs provide high flexibility but FMSs cannot handle these new requirements in a cost-effective manner. Thus, RMSs aim to produce with low cost, to enhance product quality, and to provide the changing and adjusting efficiently of the manufacturing components (hardware and software) and have the ability to respond quickly to uncertainty [3].

The literature studying RMSs is rich and covers many aspects of this kind of systems: reconfiguration optimization problem, process plan generation, part family design, scheduling problems, etc. In fact, several researchers have studied the optimal structure of this type of new systems to meet the demands of responsiveness at low costs. In practice, RMSs faced many problems because of their complex reconfigurable nature. Most of these problems are multi-objective problems, which are often treated using heuristic methods such as evolutionary algorithms [24, 25, 26,].

Besides making an overview on RMSs, their technologies and features, this paper will discuss briefly some recent researches in RMSs that applied Genetic Algorithms to find optimal configuration states as well as reconfiguration processes during the life of the RMSs.

The remainder of this paper is organized as follows: Section 2 presents a brief review on reconfigurable manufacturing system, and then the key core characteristics of RMSs are presented in section 3. The section 4 presents a comparison between the three paradigms proposed in manufacturing systems. We review a part of the literature referred to RMSs using genetic algorithms, in section 5. Finally, we conclude and give some perspectives section 6. .

II. RECONFIGURABLE MANUFACTURING SYSTEM: ORIGINS AND DEFINITIONS

In the 90th, a new class of manufacturing systems is launched to combine the advantages of classical manufacturing systems (DMLs and FMSs). This new class of systems is expected to deal with three basic aspects cost, quality and responsiveness. This kind of systems is called Reconfigurable Manufacturing Systems (RMSs). It was, the professor Koren who introduced this new paradigm and to credit with conceiving the RMS, inventing its major technologies. and defining it as "*a manufacturing system designed from the outset for rapid change in its structure, hardware and software components, in order to quickly adjust production capacity and functionality within a family of products in response to market changes or regulatory requirements*" [4, 5, 6]. Although this definition was named Koren's definition [7].

The objective of RMSs is to provide the exact capacity and functionality when needed [4]. Indeed, RMSs are considered to be a new philosophy for manufacturing [8]. These new systems (RMSs) can be developed using hardware and software components that can be rapidly reconfigured and adjusted to circumstances in the objective of minimizing the cost, time and reconfiguration effort. RMSs are expected to provide a variety of products requested by customers, classified into families, and taking into consideration the introduction of a new product, such as each configuration of the RMS corresponds to set of similar products.

RMSs can simultaneously produce multiple product types within a family in uncertain amounts [4]. A crucial feature of a RMS is that its configuration evolves over time and capable of changing of their physical structure and behavior to provide scalable flexibility; functionality and capacity; technologies and structure, when needed [9,10]. The responsiveness of an RMS includes market demands that refers to produce new product models to achieve business goals, product changes that are released by adding/subtracting functionalities to/from the current product to get a new product, and system failures that occur on hardware components or/and software components.

The architecture of an RMS composed of three main components: reconfigurable machine tool (RMT), reconfigurable process plan (RPP) and layout [30]. These three basic parts are defined as follows:

Reconfigurable manufacturing tool (RMT) is the basic and distinguished component of RMSs. It is a new type of machines with a modular structure allowing it to be reconfigured [11], thus it can be found in various configurations, and each configuration can be changed depending on the operating requirements (hardware and software requirements). The conceptualization, design and development of reconfigurable machines were initiated by [4]. It is designed to carry out a set of operations, RMTs are the most cost-effective and economical machines.

Reconfigurable Process Plan (RPP) determines the required components, machines, and their scheduling to perform all operations of a specific product. In other words, RPP assigns to each machine a set of operations that can be performed on this machine to get the desired product.

Layout: since an RMS is a reconfigurable design, thus the layout is used for adding and/or removing modules.

III. RMS CORE CHARACTERISTICS

Besides reconfigurability as an inherent feature of RMSs, there are several key enabling characteristics and technologies to realize the benefits of RMSs. In the following paragraphs, we will discuss with more details each of these characteristics.

A. Reconfigurability

Reconfigurability as a capacity has been widely studied in literature. According to [15], reconfigurability is defined as the ability of manufacturing system to be reconfigured at a low cost and in lead time. In [16], the objective of reconfigurability is to enable manufacturing responsiveness to a change in market conditions, and the authors of [7] and [17] highlighted the concept and applications relevant to reconfiguration of the manufacturing system. According to [18], reconfiguration means a modification in capability and functionality to accommodate dynamic fluctuations in market demand. Indeed, RMSs have two levels of reconfigurability: (1) in the arrangement and connections of machines at the system level, and (2) in some of the system's machines that are reconfigurable. More recently, reconfigurability is enabled by the availability of smart technologies [19, 20, 27, 28, 31, 32, 34, 35, 36, 37, 29, 30, 33, 38, 39, 40].

Reconfigurability as a capability has been widely studied in literature. According to literature [2, 5, 6, 7, 10, 21, 22], it can be decomposed into six core characteristics: modularity, integrability, customization, convertibility, scalability and diagnosability. The definitions of the six characteristics have evolved and have been enriched over time. Hereafter, we wish to mention these definitions:

B. Modularity

In an RMS environment, the modularity is a crucial aspect, where all components of the system either hardware or software are modularized and can be upgraded, reconfigured and maintained, if necessary, the components of the system can be replaced by another component in order to meet the requirements and to be upgraded to a better model with an optimal arrangement to meet the production need.

In fact, a RMS must be modular designed, cost-effective, highly productive and providing responsiveness. Therefore, RMS and their machines should be designed at the outset for reconfigurability, otherwise the reconfiguration process will be lengthy and costly, and therefore impractical [4, 5, 13, 14].

C. scalability

The scalability of the system is a characteristic that makes it possible to easily modify the production capacity. Scalability can be characterized by adding parts to a machine to increase its productivity, or by adding machines to the factory to increase the overall capacity of the production system.

D. integrability

It is the ability to put together system components quickly and efficiently through a set of mechanical, informational and control interfaces that enable integration and communication (interchangeability). The performance of the integrated system is defined and based on the performance of their components, software and interfaces.

E. Convertibility

This characteristic allows to easily and rapidly transforming the functionality of existing systems, controls and machines to suit new production requirements.

For instance, convertibility concerns the changes in the degree of freedom of the machines, or the integration, at the system level of other machines enabling the functionality of the RMS to be extended.

F. Customization

It is the ability to adapt the customized flexibility of production systems and machines to meet new needs with a family of products, and this feature of customized flexibility allows high productivity and reduces the cost of systems.

G. Diagnosability

A diagnosis aims for detecting and identifying machine failure, and discovering the root causes of the observed misconduct (product defects). As an RMS is frequently reconfigured, the diagnosis task is critical, because it is necessary to fix rapidly the problems of the newly reconfigured system, to get quality parts. There are techniques that are intended for the quick detecting of failures and their causes, and to correct them by utilizing control technologies, statistics, and signal processing techniques [5].

Finally, it is important to understand the good relationship between these six characteristics and the objectives of production systems. They improve the responsiveness and productivity of the system and also reduce the time, effort and cost of reconfiguration.

IV. RMSs vs Classical Manufacturing Systems

At the end of the 20th century, production systems were mainly dominated by two types: DMLs (Dedicated Manufacturing Lines) and FMSs (Flexible Manufacturing Systems).

A. Classical Manufacturing Systems

1) DMLs: The main objective of these systems is to cost-effectively produce one specific type of products and at the required quality. DMSs are dedicated to manufacturing a single product with a high large production capacity (mass production). The main disadvantage of DMLs is that lines are not designed to be editable. Today, DMLs disappear in many industrial companies and some companies have chosen to move towards flexible systems.

2) FMSs : To change the default, adjust the template as follows the Flexible Manufacturing Systems (FMSs) were invented in the early of 1980s [5] .

FMSs were introduced in response to the need for mass customization and to provide a high reactivity without the product changes [21]. They are known as integrated systems that are composed of some programmable forms of automation and Computer Numerically Controlled (CNC) machines that are characterized by multi-ability. The main disadvantages of an FMS are cost, complexity and low production rates [22].

RMSs are launched to combine the advantages of classical manufacturing systems (DMLs, FMSs), and to deal with the above challenges.

The three paradigms, DML, FMS and RMS can be compared based on three criteria: capacity, functionality and cost [5].

B. Comparison according to capacity-functionality

DMLs are designed to produce a product with a high production rate. This problem is theoretically treated by the FMSs, but the latter is a very costly solution and can produce any product but with low capacities, so DMLs and FMSs cannot meet the needs of the market. The solution is RMS, although RMSs is the one whose production capacity is adjustable to fluctuations in product demand, and whose functionality is adaptable to new products [1, 10, 23] the RMSs are oscillated between DMLs and FMSs in terms of capacity / functionality. In other words, DMLs and FMSs are static systems limited in capacity / functionality, while RMSs are dynamic and scalable systems whose capacity and functionality change over time according to demand.

RMSs are dynamic and scalable systems with a capacity and functionality which change over time according to demand. See Fig. 1.

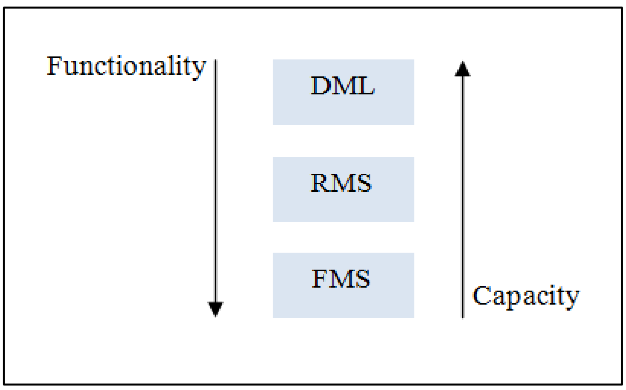

Fig. 1. Capacity / Functionality for DML, FMS and RMS.

C. Comparison according to capacity-cost

The DMLs have constant costs up to the maximum capacity of the system. In this step an additional line needs to be added as the capacity is no longer sufficient to meet the market, however, the FMSs are extensible at constant rates by adding machines in parallel. On the other hand, the RMSs are completely dynamic and scalable, which depends on the initial investment of market demand. See Fig. 2.

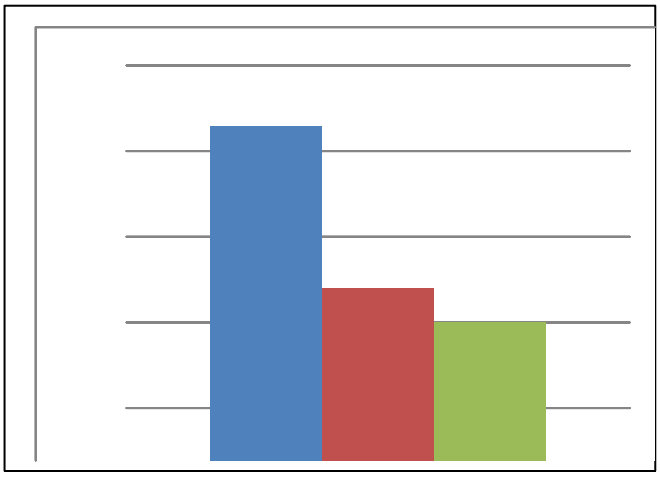

Fig. 2. Capacity / Cost for DML, FMS and RMS.

RMSs exploit the high volume production of DML and the flexibility of FMS, therefore, the RMSs are highly productive, profitable, reactive systems and they have a personalized flexibility.

V. USING GENETIC ALGORITHMS IN THE RMS

RMSs represent an active research field for more than one decade thanks to the pioneer work by [4]. In this section, a review of various papers related to optimization problem based on genetic algorithm (GA) in reconfigurable manufacturing system is reported.

We distinguish between works addressing classical single objective optimization [24, 25, 26] from those tackling with multi-objective optimization [27, 28, 31, 32, 34, 35, 36, 37] and more exactly the well know algorithm NSGA II in [29, 30, 33, 38, 39, 40].

In [24], the authors proposed a new approach based on the genetic algorithm to minimize a single objective which is the ***production cost*** represented as a process plan performance indicator for an RMS environment. The model presented the process plan as a string of Continuous variables (chromosome), and to ensure the generation of a feasible manufacturing process plan, a new method of encoding variables was applied. In [25], the authors presented a genetic algorithm (GA) for optimizing (minimizing) ***capital cost*** of multi-part flow line (MPFL) configurations of RMS for a part family. In [26], the authors proposed a method for production planning in an RMS. Their method generates the "***optimal arrangement***" to maximize the total profit and which respects the conditions or constraints of the system. An "arrangement" according to the authors is defined by the number of its series (a series is composed of a production operation with the same configuration), the sequence of the selected product families, the selected configurations and the batch sizes. The resolution approach combines a mixed integer nonlinear programming approach and a genetic algorithm. The authors consider the cost of storage, production and reconfiguration and also the time required to change the configuration of the system as performance parameters.

Unlike previous work where the optimization concerns a unique objective, the following paragraphs describe work tackling multi-objective optimization. In the work reported in [27], the authors proposed GA based approach to generate ***economical signal*** part flow line (SPFL) configurations as economical solution in RMS environment. The authors argued that "0-1 NLP" model through GA is better than the solution obtained through "0-1 ILP" model. The objectives that were considered are: reconfigurability and operational capacity and cost, in the case that only single-type product is produced. In [28], the authors used an effective GA called "**modified Genetic Algorithm method**", where a cyclic crossover operation and the combination of neighbor search based mutation operation are implemented to generate manufacturing process plans. Authors compared this new approach with other heuristics methods and the results were resulted successfully. In [31], a new Genetic Algorithm based approach is used to find a procedure that determined the most economic way to reconfigure an existing system considering the scalability feature. The rescaling of the system can happen quickly and in cost-effective manner by adding –removing machines. This approach is used to minimizing cost of the needed number of machines. In another work [32], the authors studied the problem of designing reconfigurable production lines. The line must satisfy the order of precedence of operations, accessibility constraints and other operational requirements. The problem was solved with genetic algorithms. In [34], the authors proposed a hybrid approach which combines two techniques solving arrangement problem in RMS environment. The process of reconfiguration is formally modeled by the use of the graph theory. The main objective of this work is to adopt the genetic algorithm to obtain an optimal reconfiguration path of multistage production line (one configuration to the configuration). In [35], the author proposed a new heuristic to a manufacturing strategy called IPPS (Integrated process planning and scheduling) taking into account the reconfigurabilty of RMS. deal with an optimization problem that aims to integrate the process planning and scheduling in a single function. Their idea is identifying the scheduling and the assignment of machines to operations based on the selection index of operations and the availability time of machines. The authors used a discrete- event simulated framework to fit the RMS modeling. The results of this research showed the efficiency applicability the heuristic in the term of the total completion time compared with classical sequential process plans.

The use of GA in the identification of optimal machine configuration in production lines was studied in [36, 37]. In the first work [36], the authors were interested in the optimization of performance of the reconfigurable manufacturing systems (RMSs) by maximizing its throughput. This idea is achieved by applying the genetic algorithm for the assignment of optimal machine configuration for a serial reconfigurable product flow line, this is done subject to the objective function that aims to minimize the cycle time. In the second work [37], the authors took the same problem which is selecting the optimal machine configuration for the production line; however their proposed approach considered the two objectives (minimizing the cycle time, and maximizing the operational capability) as performance parameters. Fitness function of the genetic algorithm was calculated based on these objectives that are modeled separately by mathematical functions. Authors took into account only system level configuration to obtain an optimal design of physical configuration aiming to minimize total cost (capital cost an reconfiguration) and total tardiness considered as two objective functions measuring system performance.

In [29, 30, 33, 38, 39, 40] the authors used NSGA II or some of their extensions or adapted version to make multi-objective optimization. In the work presented in [29], authors were been interested to machine reconfigurability and operational capability of RMT in an RMS environment. The authors applied in the first stage an NSGA2 multi-objective to the single-product flow line (SPFL) configuration generation to obtain the non dominated solutions, and in in the second stage, they applied a TOPSIS method to obtain an ideal solution. In the work reported in [30], the authors discussed two common problems in a reconfigurable manufacturing system (RMS) which are ***the assignment to each operation an appropriate machine*** and the ***scheduling*** of all operations to get the final product. Again, authors adapted multi-objective genetic algorithm NSGA-2 using encoding/decoding methods to solve the multi-objective problem where the generation of the dynamic optimal process plan for an RMS is done considering two objectives (cost effective and spend small time) which are modeled with a mathematical functions to perform all required operations to get the desired product. This paper illustrated an experimental example, which shows the different outputs of MOGA, and its output, which is the Pareto-front. In [33], the authors adapted a multi-objective approach to generate an optimal manufacturing process in an RMS environment; the latter is designed to be fast enough and to produce with a sufficient flexibility to react to the market changes. Authors discussed the problem of selecting the optimal configuration where a candidate machine has been selected among an available set, using NSGA2 based approach to optimally select machine configuration. They assessed tow performances parameters considering as the objective functions: minimizing the total cost including production cost reconfiguration cost, tool changing cost and tool using cost along with total completion time. In [38], the authors considered the design problem in RMS environment, where they introduced a new index to assess system robustness. Authors adapted NSGA2 Genetic Algorithm to solve the problem machines unavailability in RMS environment, where they determined the number of minimizing of two objectives which are possibilities that a process plan have to avoid perturbation and the total competition time and the perturbation. However, in [39] the authors added another performance indicator presented as objective function called robustness index to minimize perturbation of process plans. In [40], the author established a new multi-objective mixed integer program based NSGA2 genetic algorithm to integrate configuration generation and scheduling of multiple products for reconfigurable flow line in RMS environment investigating tow consecutives demand periods (DPs). Finally and recently, the authors of [41] discussed the problem of unavailability of one of the selected machines by defining the flexibility index, which represents the number of alternative machines that can avoid perturbations caused by selected machines unavailability. Authors applied NSGA-II algorithm for selecting the optimal machines, they considered two objectives (maximizing the flexibility index and minimizing the completion time). After applying NSGA-II algorithm and getting the Pareto-front, based on TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) approach authors help the decision-maker to select the best solution among the solutions of Pareto-front by ranking solutions of the Pareto-front according to preferences and abilities of the company. They followed in their approach the problem formulation and decoding technique which are proposed by [33].

VI. CONCLUSION AND FUTURE RESEARCHES

In this paper, we have made an overview about the Reconfigurable Manufacturing Systems (RMSs). This last is a new manufacturing paradigm to be cost-effective, highly productive, high performance and responsiveness. Therefore, RMS and their machines should be designed at the outset for reconfigurability. Then, we defined the characteristics of the RMS to be practical system. And finally, we highlighted previews works about the use of the Genetic algorithm in RMS environment.

The research area of reconfigurable manufacturing system is quite board and has a number of areas for future researches. Creation of a new methodology not used by researchers in the optimization field like EDA, CEDA, MODE/D, etc, and combining these methods with other methods to better investigate the reactivity of the RMSs and to design an efficient structure for the RMSs to produce several products considering other performance indicators.

References

[1] Koren, Y., « The Global Manufacturing Revolution: Product-process-Business Integration and Reconfigurable Systems », John Wiley 2010.

[2] Koren, Y., Wang, W. and Gu, X. (2016). Value creation through design for scalability of reconfigurable manufacturing systems. International Journal of Production Research, 1-16.

[3] Koren, Y. "General RMS characteristics. Comparison with dedicated and flexible systems." In Reconfigurable Manufacturing Systems and Transformable Factories, pp. 27-45. Springer Berlin Heidelberg, 2006.

[4] Koren Y., Heisel U., Jovane F., Moriwaki T., Pritschow G., Ulsoy G., Van Brussel H., « Reconfigurable Manufacturing Systems », Annals of the CIRP, vol. 48, n° 2, 1999, p. 527-540.

[5] Koren, Y., Shpitalni M., « Design of reconfigurable manufacturing systems », Journal of Manufacturing Systems, Technical paper, vol. 29, 2010, p. 130-141.

[6] Mehrabi M. G., Ulsoy A. G., Koren Y., « ReconfigurableManufacturing Systems: key to future manufacturing », Journal of IntelligentManufacturing, vol. 11, n° 4, 2000, p. 403419.

[7] Bi, Z. M., S. Y. T. Lang, W. Shen, and L. Wang. "Reconfigurable manufacturing systems: the state of the art." International Journal of Production Research 46, no. 4 (2008): 967-992.

[8] Ibrahim H. Garbie , (2014),"Performance analysis and measurement of reconfigurable manufacturing

[9] systems", Journal of Manufacturing Technology Management, Vol. 25 Iss 7 pp. 934 - 957

[10] Mehrabi MG, Ulsoy AG, Koren Y, Heytler P. Trends and perspectives inflexible and reconfigurable manufacturing systems. Journal of IntelligentManufacturing 2002;13:135-146.

[11] Hu SJ. Paradigms of manufacturing – a panel discussion. 3rd Conference on Reconfigurable Manufacturing. Ann Arbor: 2005.

[12] R.G., Min, B.-K. & Koren, Y., 2001. Reconfigurable machine tools. CIRP Annals -Manufacturing Technology, 50(1), pp.269–274.

[13] Koren, Y. "General RMS characteristics. Comparison with dedicated and flexible systems." In Reconfigurable Manufacturing Systems and Transformable Factories, pp. 27-45. Springer Berlin Heidelberg, 2006.

[14] Koren, Y., « The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems », John Wiley & Sons,2010.

[15] Lee, G.H. 1997. Reconfigurability Consideration Design of Components and Manufacturing Systems, International Journal of Advanced Manufacturing Technology, 13, pp 376-386

[16] Setchi, R.M. & Lagos, N. 2004. Reconfigurability and reconfigurable manufacturing systems – state of the art review, IEEE Conference on Industrial Informatics, INDIN'04, Berlin, June 24-27, pp 529-535

[17] Rehman, A.U. and Babu, A.S. 2013. Reconfigurations of manufacturing systems — An empirical study on concepts, research and applications, Int J Adv Manuf Technol, 66(1-4), pp.107-124.

[18] Renna, P. and Ambrico, M. 2015. Design and reconfiguration models for dynamic cellular manufacturing to handle market changes, International Journal of Computer Integrated Manufacturing, 28, no. 2, pp. 170-186, doi: 10.1080/0951192X.2013.874590.Negri, E., Fumagalli, L., Garetti, M. and Tanca, L. (2016). Requirements and languages for the semantic representation of manufacturing systems. Computers in Industry, 81, 55-66

[19] Fumagalli, L., Pala, S., Garetti, M. and Negri, E. (2014). Ontology-Based Modeling of Manufacturing and Logistics Systems for a New MES Architecture. In IFIP International Conference on Advances in Production Management Systems, pp. 192-200. Springer Berlin Heidelberg.

[20] Negri, E., Fumagalli, L., Garetti, M. and Tanca, L. (2016). Requirements and languages for the semantic representation of manufacturing systems. Computers in Industry, 81, 55-66.

[21] ElMaraghy, H. (2006). Flexible and reconfigurable manufacturing systems paradigms. Flexible Services and Manufacturing Journal, 17(4), 261-276.

[22] Zhang, G. et al., 2006. An analytical comparison on cost and performance among DMS , AMS , FMS and RMS. In Reconfigurable Manufacturing Systems and Transformable Factories. Springer Berlin Heidelberg, pp. 659–673.

[23] Dashchenko A. I., « Reconfigurable Manufacturing Systems and Transformable Factories », Netherlands, Editions Springer, 2006.

[24] Shabaka, A.I. & ElMaraghy, H.A., 2008. A model for generating optimal process plans in RMS. International Journal of Computer Integrated Manufacturing, 21(2), pp.180–194.

[25] Dou, J., Dai, X. and Meng, Z. (2010), "Optimization for multi-part flow-line configuration of reconfigurable manufacturing system using GA", International Journal of Production Research, Vol. 48 No. 14, pp. 4071-4100.

[26] Abbasi, Morteza, and Mahmoud Houshmand. "Production planning and performance optimization of reconfigurable manufacturing systems using genetic algorithm." The International Journal of Advanced Manufacturing Technology 54, no. 1-4 (2011): 373-392.

[27] Dou, J., Dai, X. & Meng, Z., 2011. A GA-based approach for optimizing single-part flow-line configurations of RMS. Journal of Intelligent Manufacturing, 22(2), pp.301–317.

[28] Musharavati F, Hamouda A (2011) Modified genetic algorithms for manufacturing process planning in multiple parts manufacturing lines. Expert Syst Appl 38(9):10770–10779.

[29] Goyal KK, Jain P, Jain M (2012) Optimal configuration selection for reconfigurable manufacturing system using NSGA II and TOPSIS. Int J Prod Res 50(15):4175–4191.

[30] Chaube A, Benyoucef L, Tiwari MK (2012) An adapted NSGA-2 algorithm based dynamic process plan generation for a reconfigurable manufacturing system. J Intell Manuf 23(4):1141–1155.

[31] Wang, W. & Koren, Y. 2012. Scalabilityplanning for reconfigurable manufacturingsystems. Journal of Manufacturing Systems, 31, 83-91.

[32] Borisovsky, P.A., Delorme, X. & Dolgui, A., 2013. Genetic algorithm for balancing reconfigurable machining lines. Computers & Industrial Engineering, 66(3), pp 541–547.

[33] Bensmaine A, Dahane M, Benyoucef L (2013) A non-dominated sorting genetic algorithm based approach for optimal machines selection in reconfigurable manufacturing environment. Comput Ind Eng 66(3):519–524.

[34] Xie, X., Zheng,B., and Xue.W,. 2013. Configuration Optimization Method of Reconfigurable Manufacturing Systems. Research Journal of Applied Sciences, Engineering and Technology, 6(08): 1389-1393.

[35] Bensmaine A., Dahane M., Benyoucef L. (2014), A new heuristic for integrated process planning and scheduling in reconfigurable manufacturing systems, Int J Prod Res 52(12):3583-3594.

[36] Hasan, F., Jain, S. & Naved Ali, S. (2014), Configuration Selection for Optimal Throughput from a Reconfigurable Product Line using Genetic Algorithm Configuration Selection for Optimal Throughput from a Reconfigurable Product Line using Genetic Algorithm, Som2014 (JANUARY 2015).

[37] Hasan, F., Jain, P. & Kumar, D. (2014), `Performance Based Optimalmachine Assignmentin Reconfigurable Manufacturing System Using Genetic Algorithm, (March), 1-6.

[38] Hadoud Benderbel, H., M.Dahane, and L. Benyoucef. 2015 "a new Flexibility Index for Machines Selection in RMS Design Problem: Multi-Objectif Approche." Proceddings CIEA Conference Proceddings Volumes (Paper online) Metz (France), October 28-30.

[39] Hadoud Benderbel, H., M.Dahane, and L. Benyoucef. 2015 "a new Robustness Index for Machines Selection in Reconfigurable Manufacturing System." Proceddings of 6th IEEE International Conference on Industrial Engineering and Systems Management (IESM), Seville, October 21-23: 1019-1026 .

[40] Jianping Dou & Jun Li2 & Chun Su1. » Bi-objective optimization of integrating configuration generation and scheduling for reconfigurable flow lines using NSGA-II". Int J Adv Manuf Technol. Springer-Verlag London 2016.

[41] Haddou Benderbal, H., Dahane, M. & Benyoucef, L. (2017), Flexibility-based multiobjective approach for machines selection in reconfigurable manufacturing system (RMS) design under unavailability constraints', International Journal of Production Research 7543(April), 1-19.