Develop of reconfigurable manufacturing plant

A V Gurjanov¹, A V Shukalov², D A Zakoldaev³ and I O Zharinov²

¹ Stock Company «Experimental Design Bureau «Electroavtomatika» named after P A Yefimov, 40, Marshala Govorova St., Saint Petersburg, 198095, Russia
² Faculty of Information Security and Computer Technologies, ITMO University, 49, Kronverksky Av., Saint Petersburg, 197101, Russia

E-mail: igor_rabota@pisem.net

Abstract. A scientific problem is how to develop automatically self-reconfigurable manufacturing plant. Self-reconfigurable manufacturing plant is a set of detailed descriptions in the level of plant models reconfigurable manufacturing systems (RMS) and RMS connection structure, which is sufficient to develop technically a plant. Primary components are described, which are necessary to create specialized system of a self-reconfigurable manufacturing plant automatic developing, which is done in the software. There is a functional scheme of manufacturing process in automatic mode for a device in a plant. There is a functional scheme of the self-reconfigurable manufacturing plant automatic developing route equipped with RMS.

1. Introduction

To develop a reconfigurable manufacturing plant [1, 2] is a multi-parameter optimization problem. The most difficulty to solve such a problem is a significant size of the project solution space within which each project alternative does not contradict to the combination of tactical (technical) requirements given to the plant. Such project problem solution without using computers is impossible today because it is necessary to develop and implement into reconfigurable manufacturing plant designer project activity several means of software and mathematics methods [3, 4].

Automatic development system for an reconfigurable manufacturing plant is a software installed on the PC, which activity is done in plants to create technical documentation for a perspective factories [5, 6]. Nowadays several software systems are developed and successfully implemented into functioning, which help the designer to create and research project solutions in the aria of the reconfigurable manufacturing plant developing [7], which manufacture «abstract» device. The primary designer interest to such software systems is concentrated on visualizing and modelling of industrial lines, functioning which characteristics are defined in the parameter level. Digital manufacturing system in this case is software as a reconfigurable manufacturing systems (RMS) interaction geometric model, which manufacture «the black box» in the dynamic mode [8, 9].

Such approach to create reconfigurable plants project automatizing systems is the first significant step to solve the self-reconfigurable plants projecting problem [10, 11]. New plants designing project perfection must be done in the direction to create models in the software projection environment of the devices being manufactured and its integration into manufacturing processes models [12]. To include device being manufactured production processes properties into models helps the plants designers to select logically RMS families and to set up parameters of its functioning so the plant being projected may satisfy the technical problem requirements in the best way.
Interaction of software and brainware and also geometric models of manufacturing operations, RMSs models and the device being manufactured models, which is being modelled in the automatic visual environment of the projection systems may help [13, 14] the plant designer to create project solutions, which can be used directly into the designing reconfigurable plants.

2. Reconfigurable plant technologies developing
The reconfigurable plant formation principles are RMS interaction mechanisms and advanced technologies to accompany device manufacturing operations completion. In the physical RMS interaction mechanisms provide manufacturing processes being completed within an flexible line. In the virtual RMS flexible technologies provide the formation of inter-workshops and inside the workshop device manufacturing routes. Device manufacturing process functional scheme and resources to provide reconfigurable manufacturing plant automatizing is shown in figure 1.

![Diagram](image)

**Figure 1.** Device manufacturing process functional scheme using advanced technologies in the reconfigurable plants.

The manufacturing physical process has two plants sections, which in sequence complete a number of operations using different type RMSs. The RMS mechanical interaction realizes device manufacturing and all of its assembly units closed loop. The sequence of the manufacturing operations being completed within each section is defined by the inside workshop plants routes.

The automatic plant inside the workshop manufacturing route can detail:

- RMS type selection, which is used to complete manufacturing operations and to calculate the specialty of each RMS;
- energy characteristics calculation consumed by a RMS while the manufacturing operation is being completed;
- material process work modes calculation being completed in the RMS chamber;
- the material consumption rate calculation being used in the additive automatic plant using RMS;
- how to choose ways and calculate parameters of the plant quality control for the device being manufactured and other.

Inside the workshop manufacturing route is formed with inter-workshop plants route and time rates calculation, which is necessary for each RMS to complete a given number of manufacturing operations. Inter-workshop manufacturing route is formed with the plants plan and the company theme and production orders placed in its cloud environment.

Algorithms accompanying forms inter-workshop and inner workshop device manufacturing routes provides virtual RMS and the digital twins of devices being manufactured. The digital twin of devices are formed by the reconfigurable plant device designer. Digital twin of RMS is formed by the RMS designer in the level of universal software and mathematical models and being adjusted by the plant inspector in the stage of the manufacturing preparation to production a competitive device.

3. Reconfigurable plant formation principle
Project problem to select physical RMS and methods of its interaction solution results are a project solution to select the reconfigurable plant. Reconfigurable plant is a detailed constitution description (in the physical RMS and its virtual RMS) and the way of interaction for all plant components. A functional scheme how to solve structure reconfigurable plant selection problem is shown in figure 2.

Project solutions based on the several methods:

- reconfigurable hardware, which provides physical processes including RMS interaction and device manufacturing;
- reconfigurable software, which controls RMSs;
- reconfigurable brainware to calculate the parameters of the device manufacturing being done;
- reconfigurable mathematical methods, which provides RMS interaction.

![Functional scheme of the solution project problem developing reconfigurable plant.](image)

Project solutions generation is done according to the each type of technical requirement (TR) and according to the principles of RMS inter-operability and advanced technologies. Project results of the project solutions generation is a set of plants sections configuration oriented to manufacture a particular
class of devices. Manufacturing of device includes project procedures in the RMS type selection and project procedures selection of the algorithms digital twins parameter set-up, which are necessary to manufacture a selected class of device.

Project alternatives set minimize (a set of sections configuration) is done using mathematical criteria of the reconfigurable plants quality. Project alternatives set reduction purpose is to reduce the project solutions space size to select the reconfigurable plant. The end result of this problem solution to create a reconfigurable plant is the technical documentation for the self-reconfigurable factory.

Technical documentation of the self-reconfigurable plant is:

- architecture schematics for the constructions and plant rooms;
- design, software and other documentation for RMS, schemes of they interaction, wiring diagrams, connection diagrams and other;
- digital twin of RMS to describe process of device manufacturing in the software and mathematical levels.

4. Conclusion

Complicated technical systems automatized projection is an actual direction today to prepare specialists in high educative companies. The Industrial automatizing is modern education tendency, where students learn flexible production technologies, which have some practical application in a self-reconfigurable plants.

The primary problems, which the self-reconfigurable plants realize is the theoretical synthesis and automatic RMSs practical realization problem, which are used in plants to manufacture an device. A perspective approach to solve RMS configuration synthesis is based on the project solutions structure and parameters optimization methods, which help the plant designers to define the best project options, which then must be realized in practice.

To justify the plant structure and enter its parameter vector it is necessary to describe in the mathematical level the RMS loading which complete inside the workshop and inter-workshop routes of the device manufacturing and documentation circulation and parts being manufactured in the plant. Self-reconfiguration plant brainware is the artificial intelligence algorithms base functioning in the cloud as a part of the plant computerized control system.

The hierarchy approach to create the self-reconfigurable plant structure explains the application of the technical and economical parameters space basis transformation methods into plant synthesis project procedures. In the hierarchy different level it is reasonable to divide the parameter space into a group of significant variables and a group of secondary parameters, which can be neglected in the current hierarchy level of the plant.

A group of reconfigurable plants relevant parameters is the project coordinate system where each project solution is represented as a vector, which describes a hodograph in the project time. A measure of hodograph proximity shows the designer the indication of similarity for each project solution to select plant structure from the technical task requirements. The best project solution must be found in the target function extremum, which use the similarity indication as an optimization parameter.

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