Hybrid additive-subtractive methods in robot assisted manufacturing

A V Shukalov, V A Dubakin and I O Zharinov
Faculty of Information Security and Computer Technologies, ITMO University, 49, Kronverksky ave., Saint Petersburg, 197101, Russia
E-mail: 131926@itmo.ru

Abstract. Additive-subtractive methods of making multi-composite metal parts combine the best technologies in a single hybrid production. Both methods used in the general production plan at the same time are justified for metal-consuming products. Each method shows its strengths when operating embedded fabricate systems with different alloys. Non-standard products with geometric nuances still make up the basic nomenclature of additive-subtractive production. Additive-subtractive solutions for enterprises are proposed, which converge both methods on the basis of complex approach. Solutions are new industrial products with the property of direct integration into production elements. The connection of industrial systems through data exchange information networks creates production models, which are controlled independently.

1. Introduction
The world industry development strategies are focused on the problem how to organize an automatic production of closed loop [1, 2]. The closed way of production is economically reasonable and includes a scaled implementation into the industry the best technological upgrades with a high share of robots and technical systems participation, which substitutes the human work [3, 4]. The closed way production basic principles are formed in the advanced Industry 4.0 concept and oriented to increase the industry competence by implementing and integration of embedded fabricate systems (EFSs) into item manufacturing processes [5, 6].

The basic difference of the Industry 4.0 concept principles from the principles of the existing Industry 3.0 concept include the human role minimization in completing most of the production operations that can be reached in deep automatizing of the industry [7, 8]. Modern solutions to make a production have a great potential to be developed and propose radical changes of the classical scheme how to organize technological sections, which creates new troubling points of the Industry 4.0 technologies practical realization on the industrial scale [9, 10].

The direct implementation of the key Industry 4.0 technologies into production infrastructure of the companies existing today cannot be realized today because there is machine and software incompatibility for the technological equipment installed in an Industry 3.0 company and advanced technologies of EFSs [11]. Company specialists’ qualifications, who surely know the Industry 3.0 technologies, today also cannot correspond to the competences which are required from the specialists who service an automatic production of the Industry 4.0 [12, 13].

The development and putting into production of analytical centers of EFSs technologies proposes a like never before transformation algorithm for the world industry [14]. Having done the key points of
this algorithm the new family Industry 4.0 companies and modernized Industry 3.0 companies, which are hybrids in a transition state with the computer numeric control (CNC) machines, EFSs, additive and subtractive production technologies [15, 16].

To synthesize a family of the Industry 4.0 new digital companies is an independent scientific-technical task, which solution is based on economic and technical methods of a multi-criteria optimization [17]. To modernize the existing project and production companies of the Industry 3.0, new organization and technical solutions must be developed to provide inter-operability of heterogeneous hardware [18, 19].

2. The Industry 3.0 production section structure
Organizing of the production activity of the Industry 3.0 industrial companies is based on equipment and technology application using the methods of CNC. The CNC machines realize the subtractive production methods and its functionality is controlled by software, which the operator puts into the machine. The Industry 3.0 production section functional scheme is given in Figure 1.

![Figure 1. The Industry 3.0 company production section functional scheme.](image)

As an example, an operator interacts with two independent CNC machines and it is a way to organize production, which result is a bunch of works converted into parts in stage by stage. The Industry 3.0 section parts manufacturing is done automatized.

The production operator puts into a CNC machine the controlling software with 3D-model part description and installs necessary sets of instruments with a piece to be processed into the machine work chamber. The machine work chamber technological process is done without the operator participation (automatically). A way to organize the production, which is based on the CNC technology, is described with the methods of Human-to-Machine (H2M) interaction.

3. The Industry 3.0 modernized section structure
A classical way to organize industrial production and to provide production technologies for a company must be modernized today. This is because the items being manufactured are complicated and the modern tendency looks into an increased level of the production processes automatizing. Means to provide the modernized production are technologies and equipment done as EFSs class.

The modern industry proposes different types of EFSs, which may function independently or as a part of the production assembly line. The Industry 3.0 modernized production section structure supposes the presence of both types of technological equipment at the same time: one that functions with CNC technologies, and one the functions with EFS technologies. The Industry 3.0 modernized production section functional scheme is given in Figure 2.

As an example of the operator interaction with EFS and two CNC machines, there is a way how to modernize the production of the Industry 3.0 company. To include EFS into a technological line, they require to implement an additional cloud server into the company production infrastructure, which contains digital models of the item being manufactured and of the EFS access to which is done remotely through IoT (Internet of Things). A way how the operator and the EFS interact is a type of H2M technologies and is done with methods of Humane-to-Systems (H2S).
4. The “Industry 3.0 plus” production section structure

To widen the industrial purpose EFSs nomenclature will help to create with it the technological sections with an increased level of production automatizing. The possibilities of existing and being projected advanced EFS define the Industry 3.0 company technological base, which is to be deeply automatized. Such a way to organize a modernized production requires a replacement for each unit of the CNC machine to something equal or higher in functions and accuracy among the EFSs. And the operator role in production “Industry 3.0 plus” cannot be excluded.

The “Industry 3.0 plus” industrial companies production section functional scheme is given in Figure 3.

5. The Industry 4.0 production section structure

The Industry 4.0 concept main idea rounds up to the production organization, in which practical realization of the production operator role is minimized or completely excluded. Such production section must be equipped with the EFS class technological equipment, which functions completely
autonomously. The Industry 4.0 automatic production section functional scheme is given in Figure 4.

![Diagram](image-url)

**Figure 4.** The Industry 4.0 automatic production section functional scheme.

The interaction example of different EFS classes reveals a way to organize the item automatic production. The EFS interaction in its physical level is done with the cross-robotized EFS with the technology of Machine-to-Machine (M2M). The EFS interaction in the cloud level is done with virtual connection services to command the EFS controller with the technologies of Systems-to-Systems (S2S).

Production personnel access to the EFS physical devices during the plant normal operation is not supposed. In the Industry 4.0 companies, all of the item manufacturing technological operations are done automatically, including loading (unloading) operations of EFS materials, elements and assembly units. The EFS interaction synchronization during the item manufacturing technological scenario completion is done with the cloud control system.

6. **Conclusion**

Today, modernization of the existing project and production companies of the Industry 3.0 can be achieved by creation of flexible automatized productions which interact with external infrastructure digital platforms. Digital infrastructure environment is based on all places distribution of the net connection nets which create the necessary conditions to power up new EFSs operatively, which are received by a scaled production.

EFSs support the technologies of the production resources united consumption placed in the digital company cloud environment. What was once considered to be the fundamental to establish an assembly and montage production, today can be reconsidered for open calculation architecture for the embedded systems of the industrial purpose.

The production environment root changes are necessary to be realized as some target software of state and private partnership, which may delete some barriers which are difficult to be overcome because a correspondent institute is not well developed yet for some sectors of the digital economy. The practical realization of the Industry 4.0 concept primary points is done with robotized solutions and different production companies structures. As for the staff, whose labor is minimized with the low qualification and medium qualification in favor of the high qualification specialists labor.

That can be prognosticated today that one of the main problems of modernizing the existing Industry 3.0 companies is a problem of the probable unbalance of the company production assets because within a single workshop, there are technological installations of different types which work in parallel automatically or automatized-ly.

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