Organization of project works in Industry 4.0 digital item designing companies

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Abstract. The task of the project works organization in the Industry 4.0 item designing digital factories is being studied. There is a scheme of the item designing component life cycle. There is also a scheme how to develop and confirm the quality of the item designing component documentation using the mathematical modelling. There is a description of the self-organization principles for the cyber and physical technological equipment in the Industry 4.0 «smart factory» company during the manufacturing process.

1. Introduction

The base of the existent world industry development stages classification system is [1, 2] basic technologies which were being applied (are being applied) in the corresponding historical period. It is accepted that the first pulse of the world industry creation was done in the end of the 18th century and closely connected with the change of the worker manual manufacturing for the industry mechanization technologies or in other words when in the industry they implemented some mechanical installations which can be controlled with the forces of water and steam. The collective name for that first stage of industrial production creation was «Industry 1.0».

The discovery of the Ohm law, the law of Coulone and others made it possible in history to electrify the production at the end of the 19th century and the creation of «Industry 2.0» when the industrial technologies of mechanization and electrification were converged. In the midst of the 20th century, the industrial electrification made it possible to create the industrial conveyor lines to manufacture the products of different purpose.

The appearance of electronic calculation technics, the implementation of programming and the CNC (Computer Numerical Control) technology as components of the production instrument supply, as well as the mechanization and electrification of production, led [3, 4] in the second part of the 20th century to the effect of automatizing technological processes, which characterizes «Industry 3.0» as an independent stage of production development.

The beginning of the 21st century became the implementation of [5-7] ideas and solutions how to organize «humanless» (smart) production in the digital economy industrial sector. The primary components of the new type production section which constitutes «Industry 4.0» are cyber and physical systems — robotized automatic technological and testing equipment which in their work may...
support [8-10]: the Internet of Things (IoT), cloud data storage technology, the technology of collection and processing of huge amounts of industrial data, additive technologies, sensors technologies and others.

2. **The convergence of industrial technologies in conditions of four industrial revolutions**
   «Industry 4.0» is a stage of world industry modern development based on the convergence of technologies of mechanization, electrification, automatizing and cyber and physical conversion of production. The realization of a practical idea on how to organize «humanless» (smart) productions of new type is supposed to include three types of «companies of the future» (see figure 1):
   - digital factory, specialized in the item designing;
   - smart factory, specialized in project and production stages of new items;
   - virtual factory, which supports technologies applied in the entire item life cycle — marketing research, technical and economical explanation of why it is necessary to create a new product until those products will be processed as morally old.
   
   The main effect expected from the «Industry 4.0» is significant automatization when the company top management, as well as project and production personnel, have to make some managing decisions, which are aimed to improve production processes of the item life cycle (see figure 2) because of automatized analysis and data processing of the item during its life cycle.

![Figure 1. The convergence of industrial technologies in conditions of four industrial revolutions.](image)

3. **The project activity organization in the Industry 4.0 company of «digital factory» type**
   The implementation of new information technologies [8-10] in project activity of the Industry 4.0 item designing company includes the transition of company personnel (designers) to the item designing rules, which are based on the governmental (inter-governmental) and branch standards of new generation.

   A digital model — an item computer model is made electronically, which describes its geometric form, dimensions and other physical properties of the item, depending on its shape, dimensions and used materials. It is supposed that the item digital model is an electronic designing document, which is a part of the construction documentation for the item. It is clear that item digital models will be
adequately equal to the real item components and may inherit the most important traits of the project activity of electronic item models of the item designing company.

![Diagram of the Industry 4.0 company life cycle](image)

**Figure 2.** The life cycle of the Industry 4.0 company (factory) item designing component.

A special trait, which proves the construction documentation quality, containing digital replica and an item digital model in an Industry 4.0 company, is an option how to conduct tests. If tests in the Industry 3.0 company must be run as some physical (natural) experiments, using a real sample of the item, but in the Industry 4.0 company the construction documentation quality can be assessed with the imitation modelling (see figure 3) of the item digital model behavior under expected (given in the technical task) exploitation conditions in a work computer of the designer automatic work place. Per se, the implementation of some virtual tests as a project procedure and gathering of some results data after the digital model imitation modelling is a step to realize practically the ideas of the item designing component documentation «digital certification».

The most important initial data for organizing virtual tests of an item designing component in an Industry 4.0 project company are a mathematical supply of the designer automatic project activity:

- item digital model (a set of construction documentation);
- digital model of stochastic influence or a mathematical description which is adequate to real climatic, mechanical and other factors of external influence, which define the expected conditions of the item exploitation;
- experiment planning methods, research methods of optimal project solutions, methods and criteria how to evaluate the project solutions quality, statistic data processing methods or virtual experiments data or others.

After some visual experiments with the item digital model, a designer may create a preliminary set of project solutions, which complies with the given exploitation requirements in the technical task. If the requirements of external influence are not defined at the level of some values, the scheme of imitation modelling shown in figure 3 gives a chance to evaluate the boundary limits of parameters of external influence, within which the item created with its digital model and technical documentation will be sustainable and stable. Those values, obtained at the stage of technical and sketch project, can be taken into account of the following versions of the item technical task and when the applicable construction documentation is created. Those alterations, especially the exploitation one, may be included into the documentation.
Figure 3. Project works organization scheme in Industry 4.0 company of «digital factory» type.

A significant advantage of that approach to the way of organizing the Industry 4.0 item designing company project activity is a possibility to generate automatically several combinations and all available options of the external influences simultaneously in the scheme of imitation modelling. The designers cannot obtain such possibility from the technological and testing equipment available today in the Industry 3.0 company. There are also some specialized types of testing chambers:
- heat and freeze which support only several cyclograms of temperature influence of the chamber work zone item;
- humidity which supports only the possibility to regulate temperature and humidity in the chamber work zone;
- atmosphere condensed rains which support only the possibility to regulate simultaneously barometric pressure, humidity and temperature in the chamber work zone and others.

In addition, all natural experiments over the item in the Industry 3.0 company are being conducted test by test, protocolling the results and correcting the prototype according to the results (documentation correction), which in total make the process of item projecting significantly longer and more expensive.

It is clear that test visualization technology or projecting in the Industry 4.0 company based on modelling does not have those disadvantages. Also it is clear that this organization scheme of the Industry 4.0 item, designing company project activity, the technical and tactical characteristics of the developed object, could be defined and that may help to determine its exploitation properties for the target user at the stage when the item itself is merely a project or a digital model.
4. The self-organization principles of technological equipment in the Industry 4.0 company of «smart factory» type

The base for the practical realization of self-organization principles of cyber and physical systems in the Industry 4.0 «smart factory» production section is the control algorithm of technological operations. The distribution of technological operations control means of the production tasks is part of the item designing component production route among the production robotized machines.

Per se the technological operations control is a classical task solution «about purpose», which is part of the linear programming task set being done by a computerized production control system in an item designing company. To solve this task «about purpose», they may apply developed and successfully used in practice algorithms of the method branches and limits, «Hungarian» methods, potential methods, simplex methods and others.

![Diagram](image)

**Figure 4.** The scheme of options how to control technological operations in the Industry 4.0 company of «smart factory» type.

The initial data to solve the technological operation control task are (see figure 4):
- at the physical level of research — technological route of the item designing component manufacturing, which is the list of technological operations which must be done one by one in the prescribed order and the technological documentation in general;
- at the cyber and physical level of research (the IoT services level) — basic algorithms library of the technological processes, which can be supported by the cyber and physical systems installed in the Industry 4.0 production.

The control results of technological operations (when the technological equipment is in the mended state) are one of the three solution options for the task «about purpose»:
- technological operation \( i \) is being done in production machine \( i \);
- technological operation \( i \) is being done in production machine \( j \);
- a group of technological operations can be done in a single production machine with the necessary production instrumentation measures (it is a task solution option when the dimensions of «task complier» and «manufacturing task» are not equal).
5. Conclusion
To improve the project automatizing processes and the manufacturing process of the item designing component in the Industry 3.0 company is one of the most significant vectors to develop the industry. The target aim of this kind of development is to create a digital innovation «humanless» production, which is oriented to collaboration with the «companies of the future»: a smart factory, a digital factory, a virtual factory.

The base for the new technological processes in those companies is the industrial Internet of Things technology, the cloud storage of data technology, sensors technology, the big sets of industrial data processing technology BigData, cyber and physical systems technology, M2M (Machine-to-Machine) technology, S2S (Systems-of-Systems) technology and others. They must give some support for the item component life cycle stages according to the main ideas of the Industry 4.0 concept.

To realize practically the development process of the Industry 3.0 industrial companies and to convert them into the Industry 4.0 digital production, it is necessary today to prepare the cadre of high quality in the correspondent fields of knowledge and specialties on the basis of specialized educational companies.

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