Industry 4.0 vs Industry 3.0: the role of personnel in production

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Abstract. The actual task is to prepare the specialists to work in the Industry 4.0 digital companies. There is an analysis of primary informative technologies and production equipment types to be used in the item designing companies of the Industry 3.0 and the Industry 4.0 smart factories. It is clear that knowledge and skills of production workers today are insufficient to complete analogue working functions in digital companies equipped with cyber and physical systems. Cyber and physical productions are created to deeply automatize the Industry 4.0 smart factories technological processes of the item manufacturing. Cyber and physical productions are applied in digital companies where functioning principles are based with the implementation of humanless and paperless technologies into production activity. There is a scheme of operator and numeric control machine interaction, which are applied in the Industry 3.0 companies. There is a scheme of cyber and physical system and operator interaction in the Industry 4.0 digital production. It is clear that the Industry 4.0 specialists preparation must be initiated today in parallel with advanced informative technologies development and production cyber and physical systems.

1. Introduction
Methods and means of the projection and high tech products production on the modern stage and corresponding informative technologies and materials predefined [1, 2] the creation of digital companies which base is the humanless ways of item manufacturing. Digital companies (smart factory, digital factory) become the main production industry unit oriented for high tech items manufacturing [3, 4].

To work in the Industry 4.0 digital companies they require [5] today the specialists with qualification much higher than the current level of production operators of the Industry 3.0. The Industry 4.0 cadres must [6, 7] acquire new knowledge and skills oriented to work in cyber and physical production division.

Personnel key working functions and working actions in the Industry 3.0 production are specialists personal presence in most technological operations, which are partially done with manual works. The Industry 4.0 automatic production with electronic technical documentation and electronic documents...
exchange in general minimize human participation in production tasks completion and in most technological operations there is no manual operations [8]. Most technological operations are done in digital companies with cyber and physical multi-operational systems and robotic manipulators [9, 10].

Work market analysis and specialists qualification level being used today in working activity shows that the production personnel quality of knowledge and skills in most cases does not correspond the competences, which are required to work in the Industry 4.0 companies. The Industry 4.0 specialists preparation has a significant back-down to the technical progress level (technological) which are presented with informative technologies and cyber and physical systems [11, 12].

So it is necessary to define the types of technological operations and ways of human and machine interactions which must be automatized firstly and its way of automatizing to create the Industry 4.0 digital companies functioning with humanless technologies (humanless production).

2. The Industry 3.0 production personnel role
The organization principles of the existing Industry 3.0 production divisions are the technologies of computer numeric control (CNC) being done with man and machine interfaces. CNC machine is a semi-automatic production equipment functioning with the control of special software. CNC machine program is done by a specialist based on the items 3D-models and schematics, which are to be manufactured with the construction documentation (CD) sets. The CNC machine program defines the blank transportation trajectory (part) and cutting (mechanizing and other types) instrument in the work chamber during the item manufacturing.

The work initial data with a CNC machine are material blanks (metal, organic glass, plastic and other) and a set of instruments. The material blank is installed by the operator into the machine working chamber in the first moving base. The instrument itself is installed on the second moving base. Bases movements to each other are done synchronically with two servo motors and a special controller. Item manufacturing process in automatic mode with «subtractive» (mechanization) technology is the result of instrument and item interaction.

CNC machine controller leading program is done by operator in manual mode according to the manuals of machine technical exploitation with the commands indicated to the operator in an integrated into machine remote control.

Each CNC machine is for different purposes of some technological operations with a limited nomenclature of the materials being manufactured. Machine properties are defined with its technical and tactical characteristics, which are in the machine technical documentation. Unification of different types CNC machine into a single production section is done according to the principles of separate technological operations completion results acceptability in the general item manufacturing route.

In figure 1 there is the interaction scheme of CNC machine and operator as a man and machine interface in the Industry 3.0 companies.

The Industry 3.0 company production division equipping with modern CNC machines may significantly increase the volume and quality of the items being manufactured without production processes deep automatizing and implementation of progressive informative technologies into production activity. Operator role in the Industry 3.0 production is in most cases only to complete preparation and finishing procedures, which may be to install a part or an instrument into machine mechanisms and deletion of finished item from the machine working chamber. Operators with high level of professional knowledge and skills are capable of accompanying the technological processes of item manufacturing in several CNC machines, which are in the same production section.

An objective advantage of the CNC machines based production is high repeatability (accuracy) of the items being manufactured. Prepared only once and approved in practice program for a CNC machine may then be used many times to manufacture a bunch of items.

To manufacture an item of new type in a production equipped with CNC machines there is no need to change primary technologies of item manufacturing and that is enough only to prepare new controlling program according to the item CD and 3D-models. CNC machines may rapidly and with
quality prepare items which technological complexity level is so high that they cannot be manufactured in a manual mode.

![Diagram of Industry 3.0 production section](image)

**Figure 1.** Interaction scheme of operator and CNC machine in the Industry 3.0 companies.

To modernize the existing Industry 3.0 companies they implement into production sections equipped with CNC machines the 3D-printers — production machines, which can manufacture an item of complicated shape with additive technologies. By uniting into a single technological cycle the 3D-printing operations and mechanization they may manufacture an item of high quality of any material and with no limits of complexity. Specialists who know how to work with CNC machines after some additional training may service the 3D-printers as well, which as well have a leading program.

In the Industry 3.0 companies they control the manufactured items quality with instruments but this can be achieved with special measuring equipment: optical stations, X-ray control machines and other. Current (by operation) quality control of technological operations completion into CNC machine work chamber is done by:
- using measuring instruments installed in the instrument shank (grooves) to manufacture the items;
- using machine integrated systems of measuring detectors.

An organization feature of the Industry 3.0 production with a pool of CNC machines to manufacture the precise (of higher accuracy) items is a necessity to meet by the company personnel some serious requirements of the production process, room and instruments:
- vibration resistance of the floors and CNC machines installation on special leveling bases;
- the application of room conditioning system to maintain a necessary level of environment temperature for the CNC machine;
- to stabilize the power supply parameters which are used to connect the CNC machines to the company main power;
- instrument support application of necessary robustness which are equal or higher to the robustness specifications of the material being manufactured;
- materials application which are planned to be used for the item manufacturing which robustness is not higher than the moving machine parts control mechanisms robustness;
- using in the CNC machine programming a system of commands compatible with the controller commands system and production machine operational system;
- material blank cutting algorithm projection (leading program) in a sequence where minimum
number of steps should be used (rotation angles) for a part and instrument between two neighboring technological operations where the machine re-adjustment is minimized and the productivity is increased and other.

3. The Industry 4.0 production personnel role
The Industry 4.0 production divisions constitution principles include the industrial purpose cyber and physical interaction technologies. A cyber and physical system (CPS) is a technological equipment to manufacture complicated technical parts in automatic mode.

Physically a cyber and physical system contains the same elements as a CNC machine after which interaction the material turns into a part. Virtually a cyber and physical system is a set of cloud services and applications (company virtual resources) to automatize deeply the production processes completion.

An interaction scheme of operator and cyber and physical system in the Industry 4.0 production is given in figure 2.

![Diagram of operator and cyber and physical system interaction](image)

**Figure 2.** An interaction scheme of operator and cyber and physical system in the Industry 4.0 production.

Each cyber and physical system installed in the production section is specialized in completion of technological operations limited number. CPSs unification into a production section is done by the principle of item manufacturing closed technological cycle. CPSs interaction processes automatizing is done by technical and program means of the robotized transport system. The robotized transport system transports parts among CPS work positions as a part of the item manufacturing technological route with the following automatic item transportation to the ready product warehouse.

CPS informative interaction held as a virtual CPS device to automatize the production processes completion is done with the net calculation equipment. CPS controllers connected to the wireless
Internet of Things (IoT) net and wired Ethernet net transmit (receive) the production data into industrial net concentrators. The net concentrators interact with commutators and router to support the information data exchange among CPSs, cloud resources and production operator.

The Industry 4.0 production operator programs CPSs and checks the production equipment control processes through the communication devices (tablet, PC, phone and other). The computerized control system grants the operator a remote access to:
- volume and quality of the items being manufactured in production;
- the condition of cyber and physical technological equipment;
- the condition of technological operations and other.

So unlike the Industry 3.0 companies with a direct interaction of technological equipment and the operator with a man and machine interface, in the Industry 4.0 automatic production the operator and CPSs interaction is done remotely.

To work in a digital company (digital factory, smart factory) which uses cyber and physical systems technology apart from the knowledge and skills which are necessary to work with CNC machines the specialists require new competences in the advanced informative technologies being used in a computerized production.

4. Conclusion

To project modern production divisions they need to implement to all stages of the item life cycle advanced components and digital informative technologies. Components and digital technologies are science and production base for the Industry 4.0 smart factory, which functions automatically and with cyber and physical systems.

Automatic production with cyber and physical systems is an actual trend of the economy production sector development. The creation of such productions will lead to the step by step development of the adjacent industry branches and science disciplines the most important of which are: material studying, solid body physics, radio electronics, photonics, spectroscopy and other.

Automatic productions projection and the following work of the cyber and physical systems interaction specialists require from the smart factory personnel professional knowledge and skills actual for the digital economy. To prepare an Industry 4.0 specialist it is necessary to create new components of educative documentation with a profile study and methods literature.

Economy industrial sector automatizing on the modern stage leads to the significant redistribution of the job market. If the company personnel role changes in next 10 years it will lead to:
- the appearance of new work occupations, which are vital for the Industry 4.0 digital companies;
- uselessness of some existing work occupations, which are vital for the Industry 3.0.

Specialists preparation knowing competences of new automatic production it is necessary to create branch competences centers with technological and cadres resources on the base of practice oriented educative programs.

Existing today practice to implement foreign technological equipment as the company production resources not only leads to the problem of the company information security but also creates a problem of the educative technologies security. New sets of educative documentation must be projected including the task of import substitution for laboratory and technical equipment engaged in the educative process of the Industry 4.0 specialists preparation.

The development of machine designing cyber and physical equipment nowadays must be done in parallel with highly qualified cadres preparation to exploit cyber and physical systems. Complex approach of the industry development and educative technologies guarantees the country priority in informative technologies and consumer markets of high tech products in the paradigm of the Industry 4.0 concept.

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