Organization of Quality Control of Manufactured Products in Smart Factories of the Industry 4.0

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Abstract. The task is to design instrument means of quality control of the items being manufactured in the Industry 4.0 item designing company. Item designing components manufacturing in the Industry 4.0 company is done automatically and that why the traditional schemes of quality check being used now in the Industry 3.0 companies cannot be used to organize new productions. There is a review of technical solutions which are used now to verify item designing components quality. There is a scheme and components which are necessary to check item designing components in the Industry 3.0 company. The advantages and disadvantages of existing procedures and equipment are described. There is a scheme and components which are necessary to check item designing components in the Industry 4.0 company where the cyber and physical systems and perspective cloud technologies, industrial Internet of Things technology are used.

1. Introduction
Automatized work places (AWP) with the nomenclature of the item designing components being checked can be classified into:
- single (narrowly specialized);
- group;
- universal.

Single AWP is a check scheme equipped technically and with program, mathematically, informatively, linguistically, organized and methodically to check, set and adjust a single unit of item being manufactured [1, 2]. All single type items are checked with single AWP in a sequence mode (in a row). The item designing components check being manufactured in the Industry 3.0 company is done automatizedly (with humans intervention) [3, 4].

Group AWP is a check scheme equipped with all necessary equipment to check simultaneously some single-type examples of the items being manufactured with a single control of checking connected to the instrument PC. If they apply group schemes of checking in an AWP it may reduce significantly the efforts of works being completed in the Industry 3.0 company and increase the volumes of items being produced keeping at the same time the item quality [5, 6].
A universal AWP is [7, 8] a scheme of checking equipped with all types of equipment to check simultaneously some items of different production nomenclature. The universal AWP key component is a control of checking and connection cables which may with minimal commutation of connection to link an instrument PC to check different types of items. In this case AWP software grants the operator to control the modes of item checking which are narrow and special in comparison to the group of items being checked. If we apply a universal AWP to check the items we may reach the results ten times faster in comparison to a single AWP.

To organize production division of new type [9] (Industry 4.0 automatic production) the new components and technologies [10, 11] must be designed and implemented which will be the base of new AWP equipped with a cyber and physical system to ensure the high quality of the items being produced.

2. Organization of item checking in the Industry 3.0 company
To check the items being produced an AWP has a set of control and measurement equipment which includes:
- amperemeter,
- voltmeter,
- oscilloscope,
- colourmeter,
and other technological equipment which helps the Industry 3.0 company personnel to detect the item defects, to provide the necessary technical specifications of items and other.

The designer of project company chooses among the units of control and measurement equipment or it also may be done by item manufacturer judging by metrology specifications of the equipment and characteristics of item being checked parameters. A list of recommended technological equipment to check the items from the designer as well as recommended schemes of checking are included into sets of construction (CD), program (PD) and technological (TD) documentations which later will be used to manufacture the item.

All types of measurement and control equipment which are parts of an AWP can be used as check schemes after a successful verifying. Control and measurement equipment have some check procedures which proves that the equipment technical specifications are according to the requirements which the equipment manufacturer stated in its technical passport and that kind of checking is being done once in two or three years. Checking controls and connection cables are being verified with marks in the technical passport as non-standard measures of measurement which requirements are given to the designers who design the items being produced.

Scheme and components to check item designing components in the Industry 3.0 company are given in figure 1.

When works of checking, setting and adjustments of manufactured items are completed in the Industry 3.0 company they initiate the item tests on the special technological equipment. Special technological equipment for test conducting includes the following types of testing chambers:
- chamber of heat and cold which checks the manufactured item resistance to the influence of high and low environmental temperatures;
- humidity chamber which checks the manufactured item resistance to the influence of high and low levels of air humidity (to create the necessary climatic conditions inside the humidity chamber it simultaneously changes the air temperature and humidity);
- pressure chamber which checks the manufactured item resistance to the influence of high and low levels of atmospheric pressure;
- atmospheric condensed rains chamber which checks the manufactured item resistance to the influence of different types of rains which appear in the environment including work solutions and aggressive media and other types of special chambers.

Also with testing chambers manufactured items quality control technological equipment includes a set of vibration stands which test the item mechanically. The mechanical tests prove that the item is resisted to different types of strike loads which influence the item in exploitation including mechanical
strikes during the item transporting from the manufacturer plant to the exploitation point in all types of transport (maritime, automobile, railroad, aviation transport).

![Diagram of item design checking process]

**Figure 1.** Schemes and components to check item designing components in the Industry 3.0 company.

3. **Organization of item checking in the Industry 4.0 company**

Control and measurement equipment in the Industry 4.0 company is known as cyber and physical systems (CPS) as items of optical and X-ray control, functional control (flying tests) and other to check automatically the manufactured items in all stages of technological operations. Item transporting to the work place of controlling CPS is done with robotized transport system which moves items within technological section (workshop) of the company from one working CPS to another.

Scheme and components to check item designing components in the Industry 4.0 company are given in figure 2.

The Industry 4.0 production company technological line is formed with a family of CPSs which connection topology is organized according to the CPS self-organization algorithms. In figure 2 there is an option how to unite CPSs with scheme «point-point» which forms the hybrid production line functioning automatically. Production machines of this line have two types of CPSs:

- CPSs to complete technological operations of item manufacturing (SMD (Surface Mount Device)-components installation on a printed circuit board, 3D-printing parts and other);
- CPSs to complete operations of production control which compare the manufactured item with the requirements of technical documentation.

CPSs of two types in linear schemes of connections of production machines is done in sequence to conduct the operation-wise control of the items being manufactured. CPSs to complete technological operations may independently as well to conduct technological procedures done quality control inside the work chamber with integrated system of automatic control. So operation-wise control of the items being manufactured in the Industry 4.0 company include the automatic procedures of:

- integrated control done with technical means of CPS (for example, quality control of separate layer application in 3D-printing on a substrate);
- operation control done with other CPS to check item in general for accordance to the technical documentation requirements.
After completion of all forms of production control they make an electronic tests protocol which is documented in the company cloud storage.

4. Conclusion
The designer does not define the order of test conduction in technical documentation for the items because in practice the manufacturer decides on their own the item tests order. So the manufacturer must choose the order of item checking which grants the maximum loads of the items being checked mode in different criteria to guarantee the consumer the item high quality speaking about the item which will be exploited.

Item load coefficient for each type of tests can be defined by the manufacturer being based on statistics data of item failures when all types of tests are conducted for a particular period of time. So item load coefficient during the tests will show the probability of failure which can be used to make an algorithm of item checking in an item test scenario with more load.

Mathematically the item check algorithm is a theory of graphs where the graph tops are equal to each type of tests and oriented ribs of graph is test sequence which numerically define the probability of item failure and time for each test conduct. Initial data for mathematical means of CPS self-organization algorithms is statistics data of item failure for each type of production tests to form the failure statistics in the company.

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