Computer control system for automatic manufacturing Industry 4.0

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Abstract. Technical solutions are proposed for the organization of technical support for automatic instrument manufacturing. The basis of the production management system is a three-level computer network. The structure of the automatic production section of surface mounting and individual technological operations is considered in detail.

1. Introduction
According to classical approaches how to organize manufacturing we can distinguish today technological, subject and linear (massive tide, serial tide, continuous tide, intermittent tide, group) ways of technological manufacturing sections organization according to the volume of on-going production and their nomenclature [1-3].
By analyzing advantages and disadvantages of given ways of organization we can see that a small level of automatizing of technological operations is realized normally with linear tide option. And also the tide lines mostly are oriented to prolonged manufacturing of low-nomenclature items according to «quality» documentation and cannot support adaptive self-organizing and adjusting properties of perspective manufacturing which are typical for technically advanced manufactures of the Industry 4.0 [4-6].
In this line the most suitable option to organize production sections of an item designing company of the Industry 4.0 is a «hybrid» solution — so called the flexible manufacture. The hybrid production sections include a set of automatic machines with memories which are destined to realize technological operations of item components creation in a programmed succession. All automatic machines have the same computerized center of control and can cinematically interact with the section transport system — industrial manipulating robot which primary objective is to carry the blanks (PCBs, components and other) between several production places in the limit of a single production line [7-10].

2. Automatic control system of the digital mechanical assembly production
Central robotized control of the mechanical assembly production is an effective tool to develop an item designing company which functions according to the principles of the Industry 4.0. The base for
the manufacturing control system is (see figure 1) a three-level informative and measuring and controlling net of the industrial Internet of Things (IoT).

![Diagram of the manufacturing control system](image)

**Figure 1.** Three-level hierarchy computerized system of mechanical assembly production control of digital item manufacturing company.

Hierarchy low level of the control system is the section technological equipment primary and auxiliary manufacturing systems equipped with controllers and condition detectors of manufacturing processes. The equipment control of production section (workshop) is done by the server which controls the servers of technological lines control.

For a complex production section (for components surface montage) several technological lines can be united in the general automatic inner-section infrastructure.

Technological lines control servers control directly the technological equipment. The upper level of hierarchy system control is the server of mechanical assembly production for information exchange with production sections control servers (workshop).

Computerized system of automatic control of the digital mechanical assembly production include:
- passive integration of digital manufacturing processes of item designing company;
- vertical and horizontal integration technological process (inner production chains) production company, which means those necessary components which creates in the company infrastructure to realize approach the Industry 4.0.

3. **Automatic section of surface montage**

Principle of organization automatic production of the Industry 4.0 can be studied logically in the example of below. Organization scheme of automatic section of surface montage of digital production is given in figure 2. The given part of scheme of the company main production.

Auxiliary part of production system in the section of surface montage includes:
- air conditioning system in the principle of climate control;
- system of drop and deactivation of water which is used to wash PCBs;
- energized system of powering automatic equipment;
- air filtration system (dust and other materials) in the production room and other.
Figure 2. Project solution scheme how to organize automatic section of digital production surface montage.

The main part of section is automatic technological equipment which can be subdivided on the principle of technological operations acceptability in four given groups:
- automatic application of solder paste on a PCB;
- automatic placement of components on a PCB;
- automatic soldering of a PCB;
- automatic washing of a PCB.

Cases of blanks, «finished products» and scrap parts consist a part of production infrastructure of an item designing company which is used to automatically store including dry storage function.

In the figure 2 there is a long option how to place manipulator robot which execute the transport functions in the production line according to the technological equipment. This option is the most suitable in comparison with cross-section and angle placement options.

When there a lot of units of technological equipment and their dimensions are huge it is reasonable to apply ring placement option of technological equipment according to the robot manipulator. The choice how to place transport robot and technological equipment can be made with the criterion of average number of materials connections among them.

4. Automatic application of solder paste
The principle of sample printing is widely known when they organize production sections of serial or low-serial manufacturing of item designing components. In this case the solder paste is applied with ribbon pressure through an aperture in the laser cut made metallic (stainless steel) sample. The volume of applied on a PCB solder material is dependent on the component type and defines with linear sizes of hole and the thickness of sample.

To maintain the technological process of solder paste application it is reasonable to use simple and stepped samples (with different thickness). The printer of sample printing can automatically made:
- PCB application;
- sample application;
- concurrence of sample and PCB;
- solder paste application when the ribbon is being run under pressure near the plate;
- removing from the sample left-over of solder.

Functionality algorithm of technological equipment which maintain the principle of dosing and sample printing and being realized with the downloaded software which is a part of delivery from the manufacturer.

5. **Automatic component placement on a PCB**

The application of automatic option of components placement on a PCB is in accordance with the principles with an item designing company functioning by the rules of the Industry 4.0 and has some significant advantages:

- significant reduction of mass and dimensions characteristics of item designing components being projected and manufactured;
- significant increase in technological signs of item designing component manufacturing;
- significant reduction of self-price of manufacturing and increase in speed (volume) of issue of item designing components;
- increase in quality of montage of components, increase the signs of reparability of item being manufactured, increase in electrical features of a via «component-printed conduct» and other.

Placement of components on a PCB is being done with special machines of placement. Trimming of solder paste (wave soldering) can be done in a single «run» of convection beam inside the oven (glue is polymerized), or one by one for which purpose the plate with already placed components is being rotated turn by turn.

For montage units which include according to the documentation some components with pin outs is being realized the principle of mixed (mixed-dispersed) montage when the placement of body elements is done on one side only and bodiless components – on both sides. In this case trimming of solder (wave soldering) always must be done in convection oven on both sides being manufactured.

A specific feature which may influence the choice of technological equipment which is a part of production line of surface montage is a step of outputs of electronic components being installed (enlisted in construction documentation) which prove the requirements of high accuracy of work of placement machine.

In case that components on the plate are of different output step it is reasonable to apply the placement option of two stages first in highly productive equipment to install the components with large output step and then in a precision machine to install the components with small step of outputs.

6. **Automatic solder of PCBs**

Temperature profile of most convection ovens consists of 5 parts in the limits of which with a programmed speed of temperature changing automatically provides:

- heating of plate with installed components (to avoid the heat strike);
- maintaining under some temperature of plate with installed components (removing of moisture, activation of flux and other);
- heating of plate with installed components to the limit acceptable value of temperature (to avoid the heat strike);
- small maintaining of plate with components in conditions of influence of limit acceptable temperature (executes the trimming of solder);
- cooling down of plate with components (to avoid the heat strike).

Solder temperature profile is unique for each type of item (plate with components) and develops in the stage of technological documentation preparation with acceptable modes of functioning (storage) of element base which is used in module.

7. **Automatic technological line of PCBs washing**

In ultrasonic washing bathes they use the liquid based on alcohol with mixtures which has the increased activity to the solder materials applying in technological equipment of surface montage.
General recommendations when choosing the washing liquid for ultrasonic bathes of Industry 4.0:
- not having chemical activity to the applied materials (components of element base, PCB material and other; we know the case when after PCB washing with installed components plant marking was partially lost);
- low viscosity and fast evaporating;
- compatibility with solder materials which includes natural and synthetic fluxes;
- activity to the left-over of solder paste, flux, solder with flux substance.

Typical project solution for organization of washing line of 4 steps of PCBs applying ultrasonic bathes is given in figure 3.

For PCBs which contains consists special types of electrical and radio items (for example quartz resonator or element components which are sensitive to ultrasonic vibration) the preference of technological equipment choice to wash PCBs it is necessary to give priority to tidal way of washing where it is reasonable to conduct pre-washing of a PCB and washing liquid.

**Figure 3.** Solution project scheme how to organize digital production section of PCB automatic washing.

8. **Conclusion**

As unique features of organization new digital production of the Industry 4.0 company we can say the following:
- the presence of automatic computerized equipment equipped with detectors of production process conditions and integration in single informative and measuring and controlled system to prepare the highly qualified management personnel in a company and ability to constantly monitor the condition of manufacturing processes in a company or in other words a transfer to «preventive» maintenance;
- the presence of algorithm and software placed in controllers of equipment and servers of production sections control (workshops, lines) which may give the processing of digital production data applying the technology of BigData cloud technologies, additive technologies and the technology of Internet of Things (data processing include automatic formation processes how to deal with the emergency measure in the production — for example equipment break-down; no more blanks in the case components or raw material which is necessary to make some technological operations and other; emergency in system of auxiliary production, — for example functionality of cleaning facilities, energizing facilities and other).

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