Design of Printed Circuit Board Production using Water Jet Technology

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Abstract **– Printed circuit boards are part of electronic devices and affect the functioning of today's society. At present, printed circuit boards are manufactured for relatively long periods of time using the same methods. The presented article focuses on the design of the possibility which eliminates errors arising from the development and etching of PCBs. It describes the theoretical design of the use of hydrodynamic continuous water jet machining in PCB production. The proposal points to the possibility of using positive water jet properties are as such: no heat-affected zone, thin separation gap, absence of dust particles and toxic fumes.**

Keywords **– Printed circuit boards, water jet, conductive pattern, hole, proposal**

1. Introduction

1.1. The Printed Circuit Boards

The printed circuit board (PCB) mechanically strengthens and electronically interconnects the individual electronic components [1].

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For this purpose, surface conductors and surfaces etched in the copper of the base material, the core of which is formed a non-conductive laminate [2], are used. PCBs are divided into one-layer (one-sided), two-layer (two-sided) and multilayer according to the number of layers. Conductivity between layers is provided by plated holes, also called mechanical vias.

Single-layer PCBs (Fig. 1) is the simplest in construction. They do not need any conductive connections between the layers. The conductive pattern is formed on only one side of the base material.

In a two-layer PCB (Fig. 1), a conductive pattern is formed on both sides of the base material. The interconnection of the layers is ensured by plated holes.

The multilayer PCBs (Fig. 1) contains conductive paths inside the base material. They are made by joining single and double-layer PCBs with insulating interlayers. They are technologically more demanding but allow easier design for more complex electronic circuits. They have better properties.

The PCB consists of a carrier plate and conductive foils. Various insulators such as paper, woven glass mat and non-woven glass fibers, carbon microfibers and foams [3] are used as carrier plate material. Phenol or epoxide is used for curing. Paper cured with phenol [4] or epoxy resin [5] is used in radio, television and measuring instruments. Epoxy glass cloth [6] is used for high-quality PCBs, catalysts. Polyester foil is used as a base material for the production of flexible conductor foils (flat jumpers).

The PCB base material is coated with one-sided or two-sided copper foil. The thickness of the copper foil is usually 35 μm or 70 μm. The overall thickness of the board (insulator and foil) may be 0.5 mm to 3.2 mm. The standard thickness is 1.0 mm, 1.5 mm, 1.6 mm and 2 mm. The size of the boards is chosen according to the application. [7]

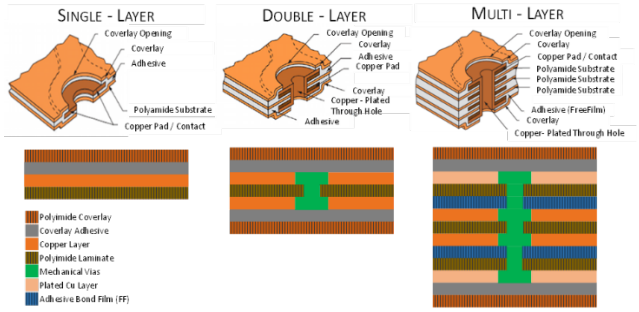

Figure 1. PCB cross-section [8]

Technologies and methods of PCB production

The design and preparation of PCB production are demanding. Production and installation can already be automated. [9] Printed circuits can be produced by various techniques. The basic processes of PCB production are: *additive*, *semi-additive* and *subtractive technology* [10].

The additive technique [11] uses a non-plated base material (washer) as the base. The principle of the method is in the creation of printed circuit elements by gradual application of conductive medium on a non-conductive substrate. The fully additive technology does not use the Cu etching process. [10]

The semi-additive technique is similar to the additive technique. Material without Cu foil is used as the base. The surface of the base material is coated with an adhesive, which must be "activated" before subsequent operations. The difference from the additive technique is that a full-area base plating of 1 to 5 µm is used. Subsequently, the printed circuit board is formed on such plated boards. With technology, it is possible to produce boards with very fine structures, with a small number of technological steps. [10]

The subtractive technique [12] is currently the most widely used PCB technology. Copper foil is clad on one side or both sides as the base material, the standard thickness of Cu foil is usually in the range from 18 to 70 µm. It is used in the production of plated and non-plated and multilayer PCBs. The basic two types of subtractive technology are Panel Plating (also known as Tenting) and Pattern Plating. [10]

The method of embedding electronic circuits by laser direct-write is also known. [13]

All the above-mentioned PCB techniques together have first operations - *drilling* and *planting*.

The drilling is performed on a coordinated CNC drilling machine based on the designed motive. It is important to set the drilling parameters correctly. [14] Incorrect drilling holes without the required quality makes it difficult to eliminate deficiencies and continue production. [15] The drilling is followed by the adjustment of the hole walls so that the base plating (metallization of the hole walls) can be realized in a certain quality.

The hole planting is performed using a combination of physical and chemical processes. The layers thus formed have a thickness of up to 5 µm. The aim of the process is to create a good conductivity of the walls of the drilled holes and to provide a good basis for the subsequent galvanic reinforcement (plating). Pre-cutting is carried out by 5 technological operations: degreasing, micro-etching, pre-immersion, conditioning, and activation. [10]

After the PCB production is finished, the surface treatment is used for better soldering conditions and a more attractive appearance. PCB finishes include: component layout, finished metallic (coating), protective varnish coating, tin stripping, PCB gold plating or silvering, grooving. [10]

1.2. Water Jet Technology

Water jet (Fig. 2) is an efficient and environmentally friendly technology that has only a minor impact on the material which is being processed. The technology is characterized by the conversion of the high-pressure liquid to high-kinetic liquid jet. High-kinetic liquid jet flows out through the nozzle and impact on disintegrated material with a high-pressure effect. The water pressure on the workpiece acts as a solid at the cut point and can range from tens of MPa to 600 MPa. If the compressive stress is high enough, unwanted workpiece particles are removed. [16]

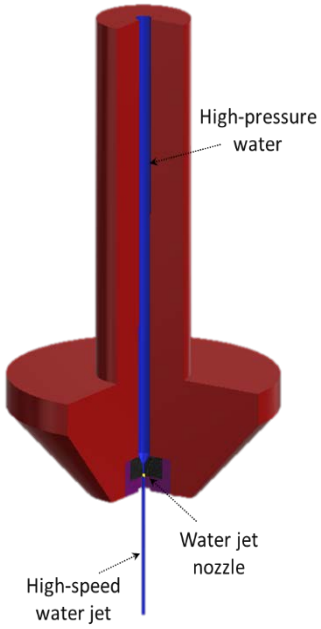

Figure 2. Principle of cutting by clean continuous water jet technology

Water as a separating medium is non-flammable and environmentally friendly. However, its physical properties are important, namely compressibility, density, temperature, and viscosity. [17]

It can be used for operations like excavation, drilling [18], [19] cutting, notching, grooving, milling, turning [20], [21], splitting [22], roughening [23], [24], crushing and cleaning any material, as well as for draining [25], breaking and mixing of multiphase mixtures.

The versatility of machining different materials is an advantage. Cutting by pure continuous water jet without the addition of abrasives is limited by the thickness and hardness of the material. Materials such as rubber, foam, thin film, paper, cardboard, soft-sealing materials, food, linen, soft and thin wood can be easily separated.

2. Defining the Shortcomings of the Current Methods of PCB Production and Proposing their Removal

The general shortcomings of current PCB manufacturing technologies are: the need for a variety of professional machinery and equipment, the need for laboratory equipment, the need for special material and materials for certain technologies, the work with chemicals and hazardous environments, environmental burdens limits, development and etching errors, errors due to drilling and finishing.

The proposal described in this article focuses on the possibility of eliminating errors arising from the development and etching of printed circuits, which are:

- *The plate cannot be developed* - The pattern is light-proof, the lighting time is short, the light source is lacking in the ultraviolet component, the developer is worn out.
- *The conductive paths have a slight contrast after development* - The illumination time is too long, the developer solution is too concentrated.
- *The photosensitive layer is in undesirable places* - The illumination time is too short, the developer solution is too weak, the development time is short.
- *The conductive paths are partially etched* - The pattern is not close to the board when illuminated, the board is too long in solution.
- *The etching process is too long* - The solution is saturated (necessary restoration), the board is insufficiently developed.

The aim of the present article is a theoretical proposal regarding the use of the technology of hydrodynamic continuous clean water jet machining in PCB production. By using water jet technology, it would be possible to overcome the problems of removing unnecessary copper during etching and development.

If the theoretical proposal described in this article was confirmed, the water jet technology could replace three important PCB manufacturing operations, namely: creating a conductive pattern, drilling the necessary holes, and cutting the PCB to the specified size. These operations could be performed by fully automating the manufacturing process using appropriate tool movement programming software. The design could also take advantage of the general advantages of water jet technology such as no heat-affected zone, thin separation gap, and the absence of dust particles and toxic fumes.

The presented proposal was elaborated in the framework of a technical study program.

3. Design of Printed Circuit Board Production Using Water Jet Technology

This chapter describes the design and technological process of the production of a printed circuit board by water jet machining technology.

The most important process before production is to design the PCB and determine for which electronic equipment the PCB will be produced. Subsequently, a scheme is made, which must be functional and faultless. Functionality, faultlessness and the resulting simulation are verified by special software and CAD systems.

3.1. Creation of Structural Design

EAGLE (Easily Applicable Graphical Layout Editor) was chosen to create the PCB design. EAGLE is a software package designed for electrical circuit design, PCB drawing and production data processing. It belongs to CAD programs and it is compatible with various operating systems. The electronic components required for electrical circuit design and PCB design are found in the database library. The advantage is also the control of the proposed scheme using the ERP tool. After checking, all errors and warnings of informative and warning characters will be displayed. Checking the diagram is very important because only the well-designed and error-free diagram depends on subsequent production and wiring functionality. After designing the schema and removing all deficiencies and errors, the schema can be transformed into the DPS Board editor, in which components are distributed to the PCB. In the editor, it is possible to set the number of PCB layers, the size of the insulation distance, the width of the surface conductor and the layout of the mounting holes. After the design is finished, the CAM

processors import the technological data for production equipment and busy machines.

3.2. Technological Design

After completing the PCB design, the manufacturing process follows (Fig. 3). The content of each production process is a technological design of PCB production. Part of the technological design of PCB production is taking, drilling and cutting of material. The final result of the production process is a finished PCB that has defined output parameters functionality, surface roughness, dimensional accuracy, and shape.

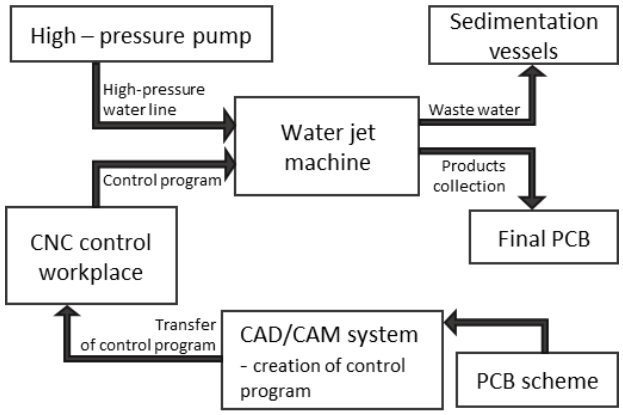

Figure 3. Scheme of PCB production process with WJ technology

3.3. Creating NC Program for Water Jet Machining

The NC program required to produce the PCB is created by extracting the necessary design data. Geometric or typological information about individual tool surfaces and toolpaths is extracted from the EAGLE PCB design. To obtain the necessary information, a direct function is used – a module that automatically saves information to the computer.

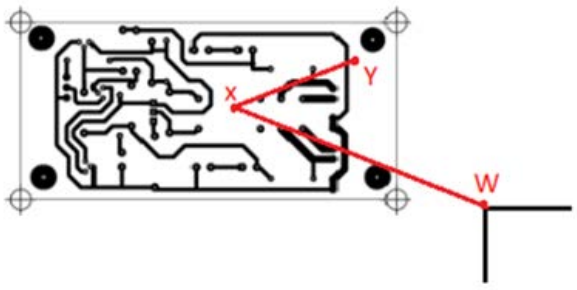

Figure 4. Arrival and departure of the cutting head

After the corrections are completed, the cutting head starts and ends the feed head. Points X and Y are plotted on (Fig. 4). These points indicate the start and end of PCB division. There are conductive paths between points X and Y, which must not be disturbed by the water jet. The W point is defined as the zero points.

3.4. PCB Production

Before production, the correct adjustment of the hydrodynamic (pump pressure, nozzle diameter, and shape) and technological (displacement head, stand-off distance, angle of incidence) dividing factors to pre-tested values on the selected materials are required. PCB production can be started after exporting the NC program to the CNC control station and simulating it.

PCB production using water jet technology consists of three operations:

- *creating holes*
- *creating a conductive pattern*
- *cutting into the appropriate dimension*

Creating holes - 1st operation

This operation creates the necessary holes and mounting holes (Fig. 5) for the electronic components. The PCB material is clamped on the cutting table and based on the NC program, by which the cutting head with the selected nozzle starts to feed the water jet to the designated locations and create holes.

Conducting pattern creation - 2nd operation

After the necessary holes and mounting holes have been formed, the blank is transferred to a second operation. The task of this operation is to remove an unnecessary copper layer with a water jet and create a conductive PCB pattern (Fig. 6).

Cutting to a predetermined dimension - 3rd operation

This operation would involve cutting the PCB into the necessary dimensions (Fig. 7), according to the cutting plan. After cutting, the workpieces are dried and continued for surface treatment.

The advantage of this proposal is the sequence of individual operations that could be performed with one technology. After the production of the PCB, the procedure is the same as in the current production technologies. This is followed by surface treatment, non-soldering mask formation, silver-plated or gold-plated contacts, and component descriptions.

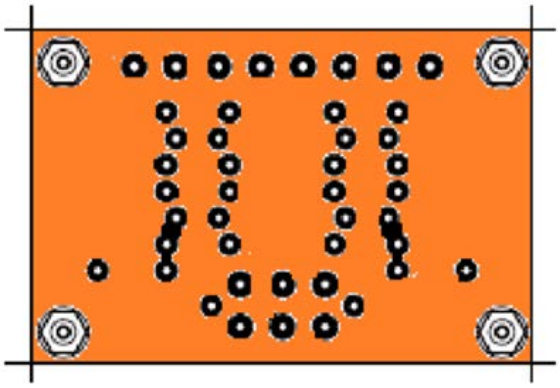

Figure 5. Designed PCB holes

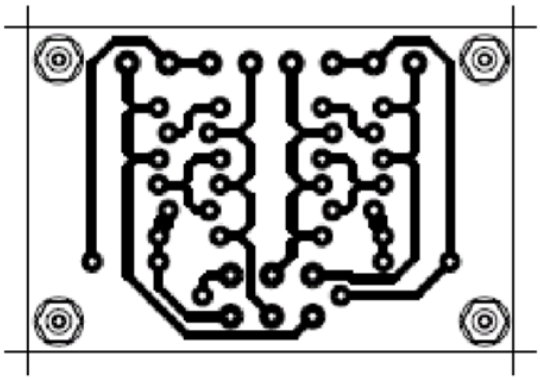

Figure 6. PCB conductive pattern

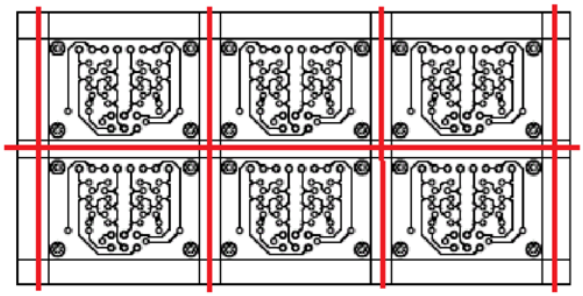

Figure 7. PCB cutting plan

4. Conclusion

The presented theoretical proposal suggests that water jet technology could be used in PCB production. The paper offers a possible solution for eliminating errors arising from the development and etching of printed circuit boards. The design offers the possibility to use water jet in creating a conductive pattern, drilling holes and cutting PCB into a specified dimension. Current methods are associated with many environmental, technological and economic shortcomings. From an environmental point of view, the new method offers increased safety at work by eliminating the use of chemicals and etchants. By means of water filtration, it is possible to reuse the separating medium. The technological advantages of changing the production process are the possibility to check and eliminate any errors in the proposed scheme and also the possibility of production simulation. From an economic point of view, total production costs could be reduced in series production by reducing the number of operations and production facilities and they could reduce the failures.

This proposal is only applicable to the production of PCBs that do not give rise to any adverse effects of water on the PCB material. The proposal needs to be elaborated in more detail and its functionality tested within real conditions. The appropriate PCB layering must be selected.

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