Proceedings IRF2018: 6th International Conference Integrity-Reliability-Failure
Lisbon/Portugal 22-26 July 2018. Editors J.F. Silva Gomes and S.A. Meguid
Publ. INEGI/FEUP (2018); ISBN: 978-989-20-8313-1

PAPER REF: 7082

MAIN EXPECTED PROBLEMS DURING THE IMPLEMENTATION OF "INDUSTRY-4.0" REFORMS AND THEIR PRACTICAL SOLUTIONS BASED ON IMPROVING THE EFFICIENCY OF USED MECHATRONIC SYSTEMS

Raul Turmanidze [1(*)], Vasili Bachanadze[2], Giorgi Popkhadze[3]
[1]Department of Mechanical Engineering and Technology, Georgian Technical University, Tbilisi, Georgia
[2]Department of Mechanical Engineering and Technology, Georgian Technical University, Tbilisi, Georgia
[3]Department of Mechanical Engineering and Technology, Georgian Technical University, Tbilisi, Georgia
[(*)]*Email:* inform@gtu.ge

ABSTRACT

This work presents the results of an analysis of the main expected potential problems that may occur in the implementation of the INDUSTRY - 4.0 reform. It is proved that the pace and level of development of this reform will largely be determined by the effectiveness of the used mechatronic systems.

It has also been established that as a result of systematic miniaturization of the nodes of radio-electronic equipment and microelectronic equipment and microelectronic technology, the main problem of these reforms and the implementation of complex technological processes is instrumental support, especially cutting micro-tools. Therefore, the examples of these micro-tools show methods for improving their performance characteristics.

Keywords: "industry - 4.0", mechatronic systems, micro tools for electro technical industry, optimization of geometric parameters of drills.

INTRODUCTION

To date, almost every scientist in any country knows and is unequivocally recognized that at the beginning of the XXI century the whole world is at the turn of the fourth scientific and technological revolution, which fundamentally should change the style and level of thinking, the rules of life for every person and especially the young generation in all countries of the world. This is due to the fact that according to many scholars and authors of large-profiled studies on the state of the necessary conditions for a worthy meeting of major reforms impending change is evaluated as the most comprehensive and ambitious in the history of mankind. It will be held under the abbreviated name "Industry - 4".

During the first industrial revolution, which lasted for more than two centuries for the mechanization of certain operations of industry water and steam were used. As a result of the second revolution based on electricity were created mass production of many products in different areas of the economy. During the third revolution using electronic and information technology production processes have become automated. Now, based on the results of the third revolution is developing the fourth revolution, which is based on digital technologies, the development of which was started in the second half of the last century. It involves a merger of several modern technologies and the disappearance of all boundaries between physical, digital and biological spheres, is the creation of a cyber - physical systems.

In other words, the final goal of the "Industry 4.0" reform is full automation and remote control of complex technological processes and administrative and financial operations by using super modern mechatronic systems.

Results of the first three revolutions were general and applicable to all countries, for each enterprise and, in practice, for each person. However, the process of the fourth degree of the revolution and the consistent use of the results of its separate stages in practice will have a peculiar character for various industries. Of course, the basic principles are common, but since each individual branch has its own special modern multicenter and multivariable technology to their design and management will need special knowledge and individual approach.

To create the above-mentioned mechatronic systems, that determine the level and pace of the development of the "Industry 4.0" reform it Requires high-precision technological equipment and special micro-tools for different purposes.

We still in the 90s of the last century made a classification of all the basic micro-tools used in microelectronics and microelectronic technology, which are divided into three main groups: Cutting, mounting and assembly. Each group includes subgroups with different tool sizes and specific areas of their use [5, 6, 7].

For a significant increase in the reliability of microcircuits and, accordingly, the final product, one more group of micro-tools must be marked - control tools - devices that enable us to check before boarding on the PCB. We can check all the operational characteristics of the microchip that is already installed on electrical, mechanical and thermal changes. We have designed, manufactured, tested and patented several options for such devices for different sizes of microcircuits and their housings. Even the technological equipment-stamps and molds for their production have been created.

After testing and selection of microcircuits for such methods, it is possible to exclude early premature failures of complex microcircuits and expensive equipment and devices during operation, which provides a great economic effect. The design and operation of the above-mentioned micro-tools will be similarly reported in the presentation.

All these tools are used quite a lot, since a significant part of modern technology, from everyday to space equipment, are a set of mechanical nodes, hydro and pneumatic equipment and microelectronic blocks or entire control systems, that is, a complex mechatronic system. For their manufacture requires the implementation of many technological operations of different profiles.

However, it should be noted that among them, especially in large numbers, cutting micro-instruments are used, especially spiral drills. This is due to the fact that in the process of producing nodes of mechatronic systems, It is often necessary to treat holes of small diameters (about 1 mm or less),especially on parts of hydro and pneumatic equipment. As for the production of microelectronic nodes, in the technological processes for the production of basic parts - printed circuit boards, a significant part of the work comes at the drilling operations of a huge number of holes of small diameter.

To obtain holes in printed circuit boards, different methods are used, but practice has shown that the most acceptable method, especially when processing multilayered PCBs with subsequent metallization of the holes surfaces, is drilling to this day.

Carry out drilling of micro carbide drill geometry, which has multiple experiments an experiences relevant production. In particular: the optimum cutting angle and spiral angle grooves respectively is 30^0, and the rear angle 18^0. They are refaced through each hole and 1000 are designed for 3-4 regrinding costs. Production of printed circuit boards is mass production, where performance is carried out with the aim of increasing the drilling package, composed of several plates, it has a place of deep-hole drilling, where the drill depth exceeds the diameter of 8-10 times.

Downtimes of expensive technological equipment, especially in mass production are associated with significant economic losses. In the production of printed circuit boards easy connected not only with the replacement of the tool with the aim of reshaping, but unexpected, caused by fragile destruction even before the first reshaping. Probability of brittle fracture grows significantly during deep drilling package of printed circuit boards when this zone is located in the near destruction of the end of the spiral grooves.

Providing the best mass production processes for manufacture of printed circuit boards, at least a slight increase in resistance, including fragile resistance micro drills and consequently increasing productivity processes, can provide significant economic benefits.

THE MAIN PART

Research work with a view to enhancing the resistance of tungsten carbide micro drills and deep hole drilling process performance package of printed circuit boards were held in the laboratory precision micro instrumental Department "Industrial Technologies Engineering Mechanics", Georgian Technical University in close cooperation with specialists of the Institute of Manufacturing Technology and Quality Management (IFQ) Magdeburg University Otto-von-Guericke (Germany).

Studies were initiated the study of the nature of the change of power indicators-torque and axial reinforcement depending on the depth of cutting and drilling printed circuit board package from fiberglass.

To measure the axial effort was the appliance is made on the basis of known methods and existing analogs, measuring element, which is the system of strain gauges mounted on the elastic casing. (Figure 1).

As for measurement of a torque, in our case the existing indirect method at which measurement is carried out by means of measurement of power of process of cutting is unsuitable as we deal with very low indicators. That is why it is necessary to use this method, which will make it possible to measure directly the torque with high precision. To this end, we have designed and manufactured a special device, (Figure 2) in which table for drilling is equipped with rotating lever mechanism. As the measuring element, elastic element applies here too with the system of load cells, only the higher strain measure (Sensitivity 0.1 gram).

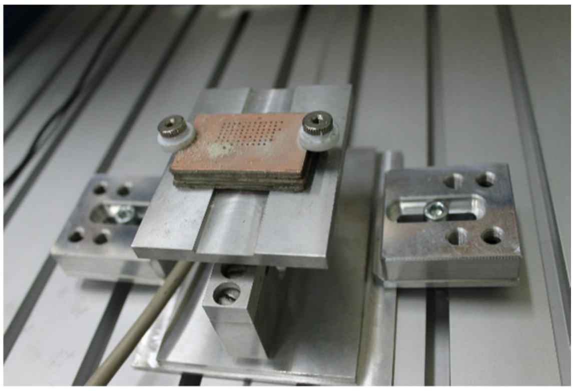

Fig. 1 - Instrument for measuring axial efforts.

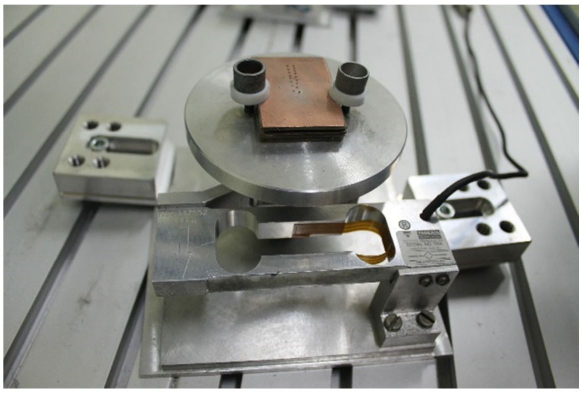

Fig. 2 - The device for measurement of torque.

Experiments were conducted with drills from solid alloy VK60M diameter φ 0,9mm long spiral groove l=10mm. Rake angle and spiral angle grooves respectively $\omega=30^0$, rear angle was 18^0.

Drilling was carried out a package of printed circuit boards of fiberglass thickness 1.6mm composed of 5 plates with a total thickness of 8mm (see Figure 3).

Drilling of blanks is carried out on different modes of cutting depth up to 7 mm and 1 mm the depth of the recorded testimony every depth controlled readings. Experimental results are shown in Figures 4 and 5.

From this results, clearly shows that the load power with increasing depth progressively increasing. If the axial thrust is growing, approximately 1.5 times the amount of torque is increased 3-4 times.

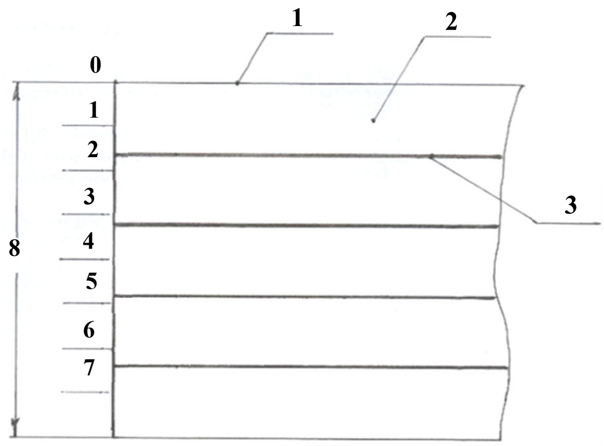

Fig. 3 - Package diagram printed circuit boards of 5 plates.
1-copper foil, 2-fiber, 3-double layer of copper foil.

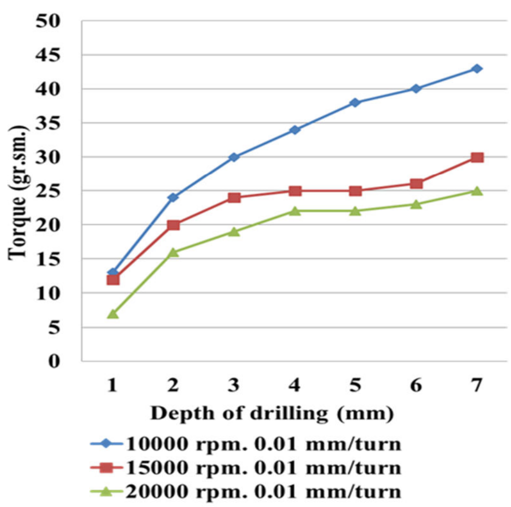

Fig. 4 - The chart for standard drills $\omega = 30^0$.

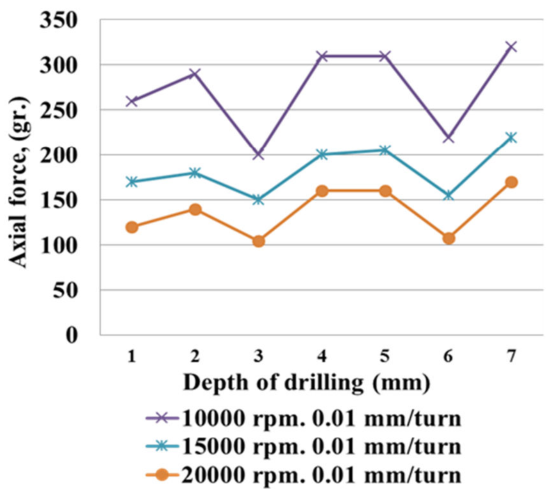

Fig. 5 - The chart of axial efforts for standard drill $\omega = 30^0$.

Question, what caused this increase in power? Cutting conditions at the cutting edge of drills with increasing depth does not change. The only reason for this could be the increased contact area abrasive chips with the surface of the hole and emerged from it frictional forces.

You need to note that the sharp fall in axial efforts on areas of depth 2-3 and 5-6 (see Figure 5) on these sites due to the lack of the work piece (Figure 3.) the copper layer.

The main factor increase the likelihood of brittle fracture of the cutting tool of these two power indicators may not increase the axial effort and more progressive increase in torque because the strength properties of carbide materials on the compression significantly exceed indicators of torsion.

Accelerating the process of chips from the cutting zone would contribute to the reduction of the force of friction and, consequently, improve the reliability of the drilling process. The problem of removal of chips when drilling deep hole in different cases decide in different ways. For example, when drilling drills dimensions solid this exercise method of leaching using a coolant, which is supplied, into the hole through, done in the body of the drill. In other cases, when the drill bit sizes do not give possibility of coolant above method to remove shavings used drilling method intermittent, where after a certain depth drilling is carried out periodically by the disqualification of drills from holes fast running.

The application of these techniques in our case nepriemlim. In the first case we have with micro drills. The use of coolant in the manufacture of printed circuit boards is not allowed. Design and method of intermittent drilling, because it led to the strong performance, when processing deep eyelet micro drills accelerating factor could be an increase in chip removal step spiral grooves, i.e. reducing the angle, but it would have led to a deterioration of the cutting conditions, so-as will decrease the cutting angle drills.

In the design of the drills carried out in a way that at the top of the save the desired cutting angle, and toward the end of the spiral grooves reduce its angle, IE a spiral groove cut into a vary-angle [1, 3, 4] and gradually increase its step, it would accelerate the process of chip and facilitate conditions for drilling.

Figure 6 shows the scheme of drills with vary-angle spiral grooves where the angle of the grooves at the top of the drill ω_0, and at the end of the working part of ω_1. The width of the grooves in the normal section B_n on all length does not change, but the change in the front section and at the top is $B_{To} = \frac{B_n}{\cos\omega_0}$, and at the end of the working parts $B_{T1} = \frac{B_n}{\cos\omega_1}$.

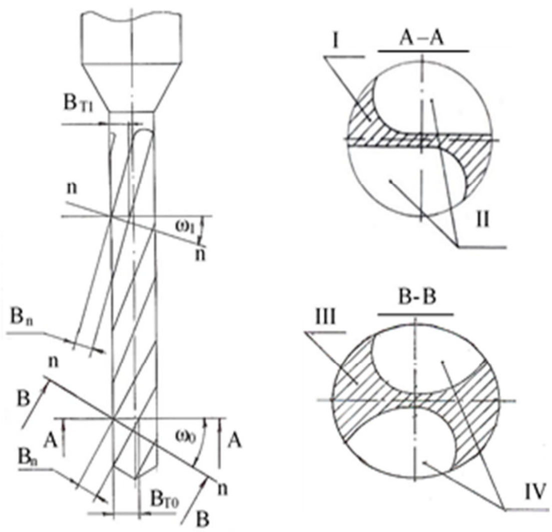

Fig. 6 - Drill scheme with variable angle of inclination of the spiral grooves.
AA is the section of the drill of the plane perpendicular to its axis: I - Useful area of the drill, II - Groove profile.
B-B - section of the drill in the plane of the perpendicular spiral grooves: III - Useful area of the drill, IV - Profile of the drill.

Changing and useful mechanical drill section. Useful section at the top: $S_o = \frac{\pi d^2}{4} - \frac{2S_n}{\cos\omega_0}$, and at the end of the working parts: $S_1 = \frac{\pi d^2}{4} - \frac{2S_n}{\cos\omega_1}$, where S_n - square grooves in the normal section, d - is the diameter of the drill.

If you take into account that $\omega_0 > \omega_1$, it turns out that toward the end of the working part of the useful cross-section drills intensifies. Then there are drills compared to standard must withstand stress.

Production of such drills associated with certain difficulties. At production of standard drills with a constant tilt angle of a spiral flute the special adaptation carries out the mutually agreement two movement - rotations of preparation of a drill and its movement in the axial direction at a size of a step of a spiral flute. Thus, this interrelation is defined by linear function. In case of a variable step, this interrelation is defined by difficult tangential function. Because of it was necessary to modernize the equipment and its mechanism of axial giving of an element with the Archimedean spiral to replace elements with a tangential spiral, made by our special calculations [2, 3].

Besides, because of a variable tilt angle of a spiral flute, at you - polishing of these flutes should change orientation of a grinding wheel relatively to an axis of preparation of a drill respectively to change of a tilt angle of a flute. It can be carried out in two ways: at a motionless axis of a grinding spindle to turn a preparation spindle axis round a point of intersection of these axes at a corner size $\omega = \omega_0 - \omega_1$ (see Figure. 7), or motionless to leave an axis of a spindle of preparation and to turn an axis of a grinding spindle (see Figure 8) [4, 5].

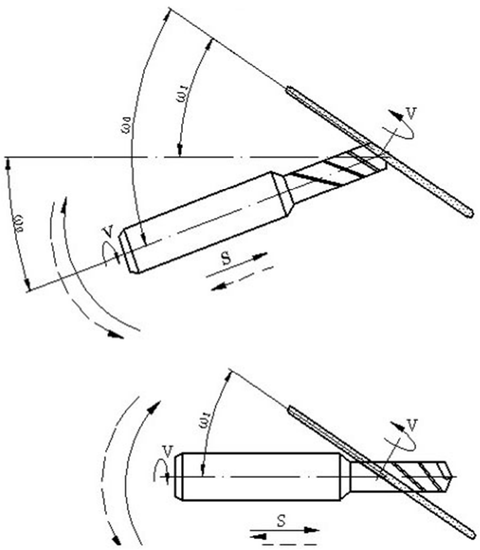

Fig. 7 - Schemes of change of orientation of axes of a spindle of preparation of a drill and grinding spindle. Method of turn of an axis of a spindle of preparation.

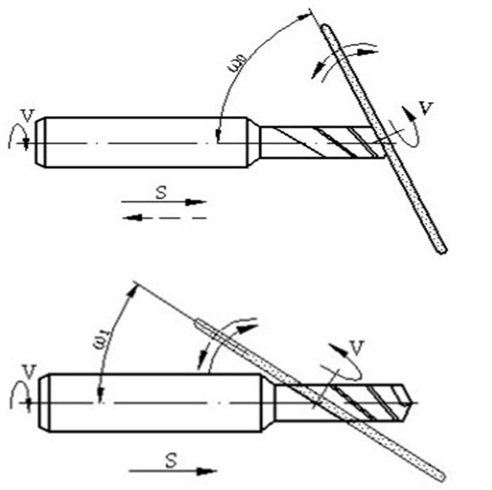

Fig. 8 - Schemes of change of orientation of axes of a spindle of preparation of a drill and grinding spindle. Method of turn of a grinding spindle.

Proceeding from constructive reasons the preference was given by us to the first option (Figure 7) and in the course of modernization of the equipment it was equipped with the additional mechanism of turn providing when cutting spiral flutes, turn of an axis of preparation of a drill relatively to an axis of a grinding spindle at a corner size $\omega = \omega_0 - \omega_1$ thus depending on are long the cutting part of a drill turn is carried out by the linear law: $\omega_x = \lambda_x \cdot K_\omega$, where ω_x - the current size of an angle of rotation of an axis of preparation, λ_x - the current coordinate of length of the cutting part of a drill, K_ω - the size of change of a tilt angle of a spiral flute per unit length the cutting part of a drill.

Schematic diagram of the upgraded device with a lever turning mechanism is shown in Figure 9. It should be noted that with the purpose to achieve higher precision in return lever mechanism can be used rack and pinion pair.

Device for polishing spiral grooves in the side of the work piece 1 is mounted on the drill axis of rotation 2, mounted on a grinding machine table - 3D642. In this case, the axis of rotation adaptation must take place at the point "O" crossing the axis of the drill blanks and the vertical axis of symmetry of the grinding wheel 3. The other end of the device is based on a circular guide 4. Rotate lever mechanism is carried out, the reference axis 5 which is fixedly mounted on the basis of 6 devices. When the axial movement of the upper slide 7 and, accordingly, drill blanks rigidly associated finger 8, turns right shoulder of the lever 9. The left lever arm is connected to finger 10 fixedly mounted on the machine table. Thus, the rotation of the lever causes the whole structure adjustment. Thus, the linkage elements are designed so that the axial feeding blanks on a drill length value helical cutting tool is rotated by the movement of the spiral groove inclination angle $\Delta\omega = \omega_0 - \omega_1$.

For this calculated distance between the left finger and fixedly pivot device formula: $R = l \cdot \frac{L_л}{L_п} \cdot \frac{360}{2\pi\Delta\omega}$

Where: l - the length of the spiral cutting drill, mm;

$L_л$ - left lever arm length;

$L_п$ - the right lever arm length;

$\Delta\omega$ - amount of change in the angle of the spiral grooves of the drill

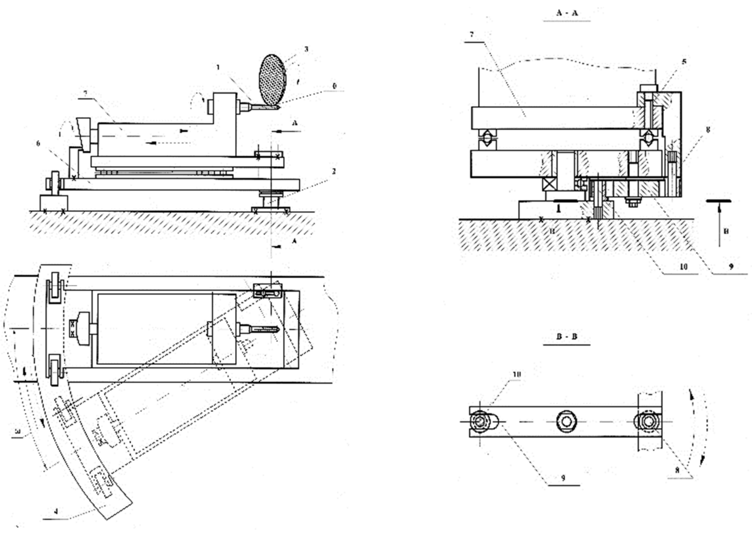

Fig. 9 - Schematic diagram of the rotation axis of the drill mechanism workpiece relative to the plane of the grinding wheel at Grinding of helical grooves with a variable tilt angle.

We have designed constructed prototypes of drills with vary-angle $\omega = 30 - 17^0$, $\omega = 35 - 20^0$, $\omega = 40 - 22^0$ and $\omega = 43 - 23^0$.

All of these included circuit boards same experiments as the standard. Experimental results for drills $\omega = 30 - 17^0$ and $\omega = 35 - 20^0$ are shown on Figures 10 - 13.

Analysis of these graphs shows the following: for drills $\omega = 30 - 17^0$ performance of axial efforts almost indistinguishable from a standard drill bit $\omega = 30^0$, so, it was expected, because these same drill front angle and cutting conditions respectively at the cutting edge. With regard to indicators of torque, they drill $\omega = 30 - 17^0$ depending on the cutting was understated by 12-16%.

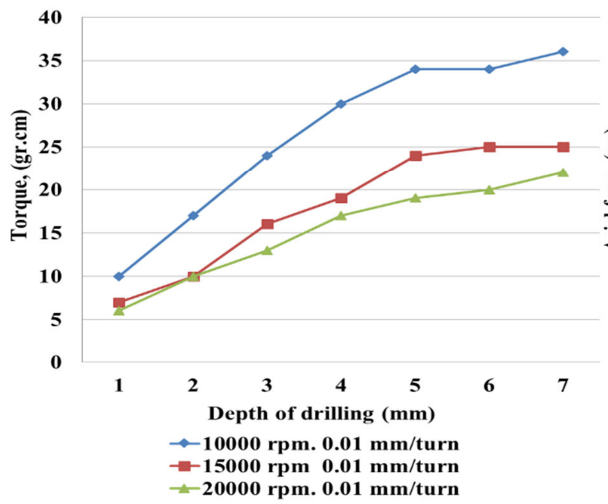

Fig. 10 - The chart of change of a torque for drills $\omega = 30 - 17^0$.

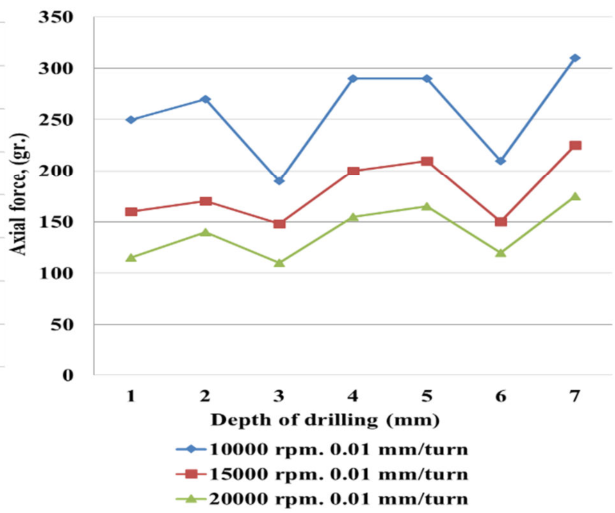

Fig. 11 - The chart of changes of axial efforts for drills $\omega = 30 - 17^0$.

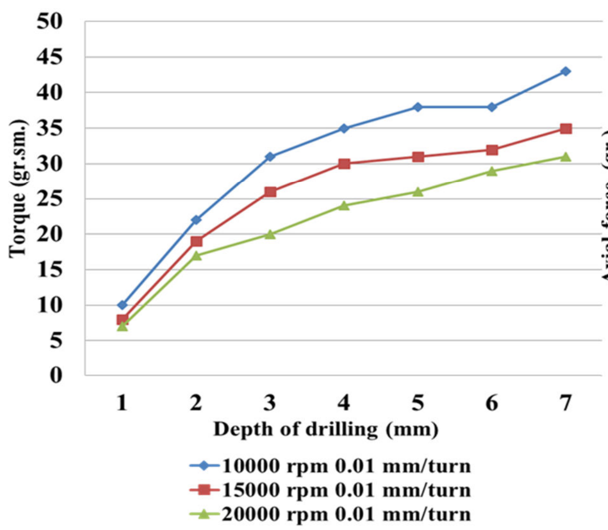

Fig. 12 - The chart of torque for drills

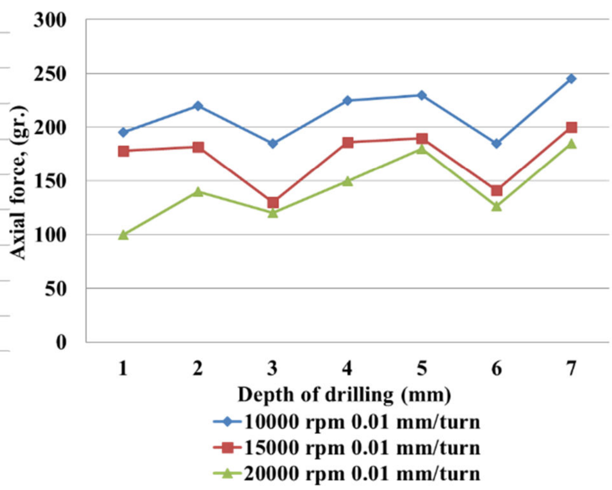

Fig. 13 - The chart of changes of axial efforts for drills $\omega = 35 - 20^0$.

For drills $\omega = 35 - 20^0$ performance of axial efforts relatively understated, as rake angle increased by 5% and this facilitated the process of cutting, but indicators of torque with increasing depth drilling grows more intensively and exceed indicators of both previous designs. It is clear that the understatement of torque to drills $\omega = 30 - 17^0$ compared with standard drills $\omega = 30^0$, due to the gradual increase in step spiral grooves and accordingly reduced contact area formed by chips with processed apertures. Increasing the angle of inclination and therefore a decrease in pitch of spiral drills $\omega = 35 - 20^0$ again causes the reverse-torque figures intensively promoted.

When drilling by drills of $\omega = 40 - 22^0$ and $\omega = 43 - 23^0$ these power indicators are rather underestimated (see Figures 13-16) that is explained by improvement of conditions of cutting because of considerable (5-8^0) increases in a forward corner at the cutting edge. However, reduction of a corner of a point at further operation causes increase in intensity of wear, and they without repoint reach only 600-800 openings.

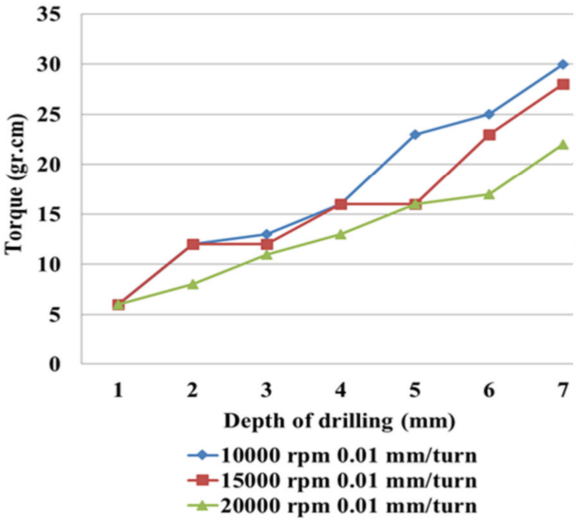

Fig. 14 - The chart of change of a torque for a drill $\omega = 40 - 22^0$.

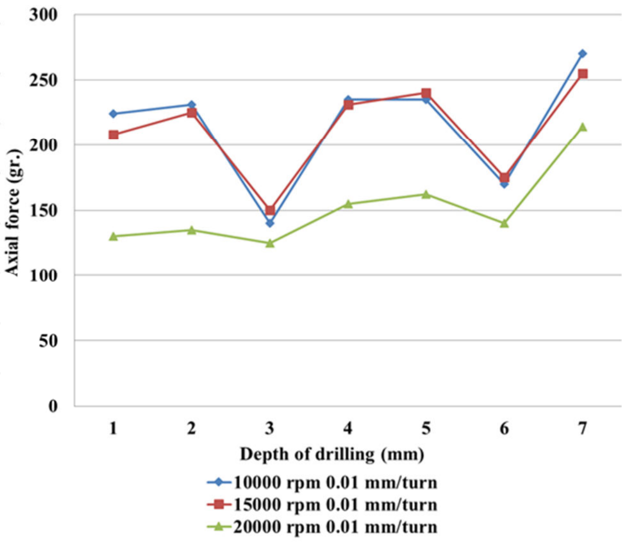

Fig. 15 - The chart of change of axial effort for drills $\omega = 40 - 22^0$.

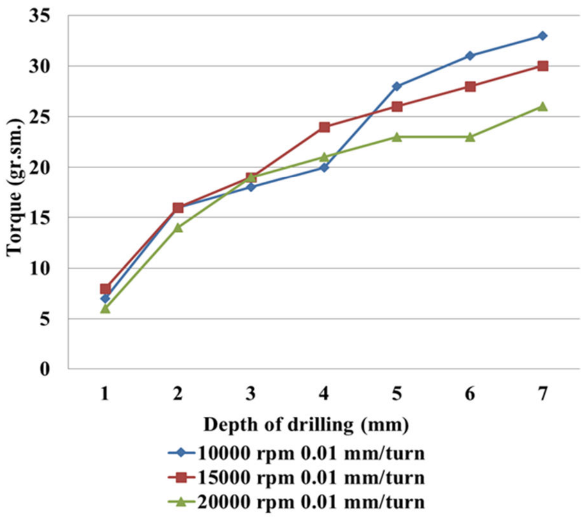

Fig. 16 - The chart of change of a torque for drills $\omega = 43 - 23^0$.

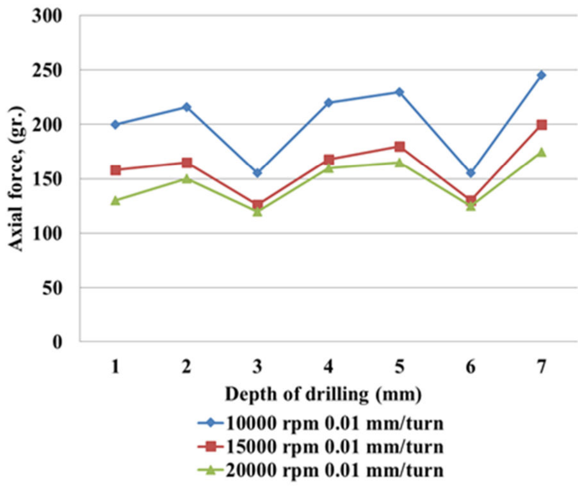

Fig. 17 - The chart of change of axial effort for drills $\omega = 43 - 23^0$.

Obviously, to get a clearer picture further experiment need to keep standard drills $\omega = 30^0$ and drills with vari-angle spiral grooves $\omega = 30 - 17^0$. Experiments were continued until the breakdown drills. Through each hole 200 checked power indicators, with increasing cutting edge wear gradually increases. After 1000 holes check carried out through every 100 holes, as increasing the likelihood of breakage of drill. Throughout a series of experiments for both types of drills, $\omega = 30^0$ nearly identical indicators remain innovative wear and axial efforts. As for torque, its value on the standard drills always exceed the value of drills with variable angle of the spiral grooves $\omega = 30 - 17^0$.

Statistics showed that the breakage of the standard drills $\omega = 30^0$ going from 1200 to 1300 holes and drill with vari-angle $\omega = 30 - 17^0$ from - 1400 to - 1500. Performance torque values before breakdown indicating the number of drilled holes N traversed the path L and size of wear on back surface drills f shown in Figures 18 and 19.

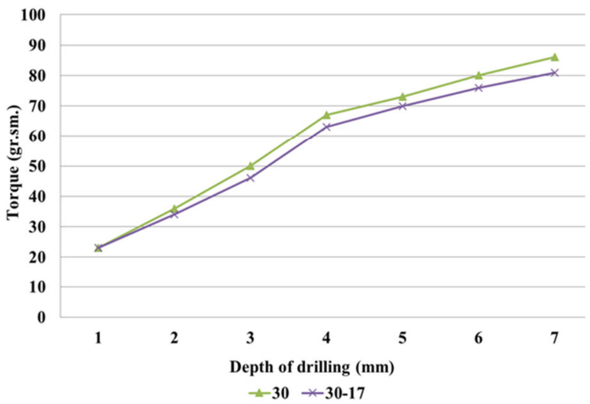

Fig. 18 - The chart of torque graph for drills $\omega = 30^0$ and $\omega = 30 - 17^0$ before the breakdown drills

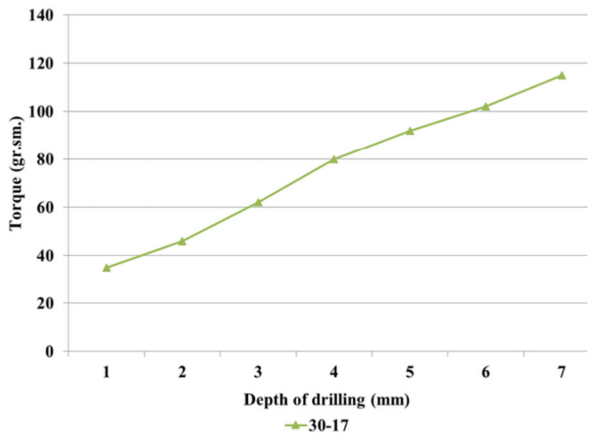

Fig. 19 - The chart of change the torque diagram for drills $\omega = 30 - 17^0$ before its breakdown.

RESULTS

To create the above-mentioned mechatronic systems, that determine the level and pace of the development of the "Industry 4.0" reform it Requires high-precision technological equipment and special micro-tools for different purposes.

The presented report will show the classification of the micro-tools used for the production of the main units of modern mechatronic systems, as well as ways of systematically improving the efficiency of the used individual instrument groups, taking into account the process of intensive miniaturization of radio electronic equipment and increasing the level of requirements for their performance characteristics.

CONCLUSIONS

It is established that the rate of development of the INDUSTRY-4.0 reform in a strong degree depends on the efficiency of the Operational characteristics of the used mechatronic systems.

It is proved that the output characteristics of individual nodes of the used mechatronic systems can be significantly improved by optimizing the design and geometric parameters and the manufacturing processes. For example, the hardness of hard-alloy precision spiral drills with a working diameter of less than 1 mm and the productivity of drilling of printed circuit boards can be increased by at least 20-25%.

By optimizing the geometric parameters of carbide micro-drills, it is possible to significantly improve the chip formation process and their free removal from the cutting zone when drilling printed circuit boards, which positively affects the quality of the treated surface and subsequently its metallization.

REFERENCES

[1] A. Ivan, Research regarding optimization of industrial robots for machining applications, Doctoral Thesis, Universiti “Politehnica” of Bucharest, 2011.

[2] Карпушевски Б., Дюбнер Л., О. Кушнаренко О., Турманидзе Р.С. Erhöhung der standzeit und prozesssicherheit von mikrobohrern durch die entwicklung neuer werkzeuggeometrien. Сборник научных трудов «Современные технологии в машиностроении». Харьковский национ. техн. университет "Харьковский Политехни-ческий Институт", Харьков, Украина. Выпуск 2. 2008 г. стр. 27-32.

[3] R.TurmanidzeV.Bachanadze, G.Popkhadze International saintific journal “Inovations”. Year V, Issu 3/2017, Sofia, Bulgaria,ISSN Print 1314-8907,ISSN WEB 2534-8469123-128.Basic technological processes required to create mechatronic sistems to meet today's needs and problems of their instrumental support of “Industry 4.0” challenges

[4] Снова перемены. Как выглядит Индустрия 4.0? available at: http://hi-news.ru/business-analitics/industriya-4-0-chto-takoe-chetvertaya-promyshlennaya-revolyu ciya.html

[5] Турманидзе Р.С., Бокучава Г.В., Новые процессы алмазно-абра¬зи¬в¬¬ной обработки. Тезисы докладов Первого всесоюзного съезда техно-логов-маш. г.Москва, 13-18 ноября, 1989г. 12 стр.

[6] Турманидзе Р.С., Амиридзе М.Н., Микроинструменты для сборки и монтажа микросхем и технологи¬ческое обеспечение их изготов¬ления. Тезисы докладов междунаро-д¬ного семинара "Высокие технологии в машинострое-нии". Харьков-Алушта, 1992г. 3 стр.

[7] Турманидзе Р.С., Некоторые особенности проекти¬рования и изготовления твердос¬плавных прецизионных микро-инструментов. Труды Харьковского технического университе¬та "Резание и инструмент", вып. 50. 1995г. 2 стр.

[8] Карпушевски Б., Дюбнер Л., О. Кушнаренко О., Турманидзе Р.С. Erhöhung der standzeit und prozesssicherheit von mikrobohrern durch die entwicklung neuer werkzeuggeometrien. Сборник научных трудов «Современные технологии в машиностроении». Харьковский национ. техн. университет "Харьковский Политехнический Институт", Харьков, Украина. Выпуск 2. 2008 г. стр. 27-32.

[9] Турманидзе Р.С., Адамия Д.Р., Гвиниашвили З.М. Особенности изготовления и испытания мелкоразмерных твердосплавных спиральных сверл с переменным углом наклона стружечных канавок. Сборник трудов XVII международной научно-технической конференции «Машиностроение и Техносфера XXI века». Донецкий Национальный Технический Университет. Том 3. 13-18 сентября 2010 г. в. г.Севастополе. стр. 181-184.