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OPTIMIZATION OF GEOMETRIC PARAMETERS OF HARD METAL MICRO DRILS TO INCREASE TOOL LIFE AND PERFORMANCE OF DRILLING PACKAGE OF PRINTED CIRCUIT BOARDS

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Abstract: *In the presented work, there are investigated the changes of power characteristics of deep drilling package of printed circuit board's hard-alloy micro drills depending on the drilling depth, cutting data and geometry of the drill. In particular are studied the nature of changes in axial efforts and torque depending on the drilling depth drill with different inclinations of the spiral grooves using specially designed highly sensitive devices, enabling direct measurement method. On the basis of the analysis of results of research are made the changes in geometry of the existing standard drills. New construction of micro drills vari-angle spiral grooves in such a way that the angle is the maximum value at the top of the drill and uniformly decreases towards the end of the working parts are suggested. The drills are manufactured with different inclinations of the spiral grooves. On the basis of experiments of them chosen more for its close standing power rates to the standard drill bit and its comparative test with a standard drill bit, bringing them up to the breakage, thanks to which the proven advantages of drills new design. Taking into account the results of the experiments, there are suggested drill elongated structures to improve performance by increasing the processing drilling depth and accordingly the number of plates in the package of printed circuit boards.*

Key words: *drill, gradient of spiral groove, variable angle, device.*

1. INTRODUCTION

It is impossible to imagine modern equipment without electronic knots, starting from household and ending with space equipment. Production of printed circuit boards, basic parts of electronic equipment is connected with process of drilling of a huge number of openings of small diameter holes (about 1mm or less). Drilling is carried out by drilling of micro carbide drill, which geometrical parameters are established by repeated experiments and experiences of the corresponding productions. In particular: the optimum cutting angle and spiral angle grooves respectively is 300, and the rear angle 180. They are refaced through each hole and 1000 holes 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 production of printed-circuit boards, idle time is connected not only with the provided replacement of the tool for the purpose of their repointing, but also unforeseen, caused by fragile destructions even to the first repointing. Probability of brittle fracture grows significantly during deep drilling package of printed circuit boards. Thus, the zone of destruction is in nearby end of a spiral flute.

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.

2. 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).

Researches were begun with studying of nature of change of power indicators – a torque and axial strengthening depending on depth and the modes of cutting of

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Fig. 1. Instrument for measuring axial efforts.

drilling of a package of printed-circuit boards from a fiberglass.

For measurement of axial effort the device on the basis of known methods and the existing analogs, was manufactured by the measuring element of which the system of strain gages mounted on the elastic case (see Fig. 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 (see Fig. 2), in which table for drilling is equipped with rotating lever mechanism. As a measuring element here the elastic element with system of strain gages, only higher accuracy of measurement (0.12 grams) too is applied.

Experiments were conducted with drills from solid alloy VK60M diameter φ = 0.9 mm long spiral groove *l* = 10 mm. Rake angle and spiral angle grooves respectively ω = 30°, rear angle was 18°.

Drilling was carried out a package of printed circuit boards of fiberglass thickness 1.6 mm composed of 5 plates with a total thickness of 8 mm (see Fig. 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 Figs. 4 and 5.

From these results, it is obviously visible that, as well as it is expected, power loadings with increase in depth progressively grow. Thus if the axial effort grows about 1.5 times, the size of a torque increases 3–4 of time.

Fig. 2. The device for measurement of torque.

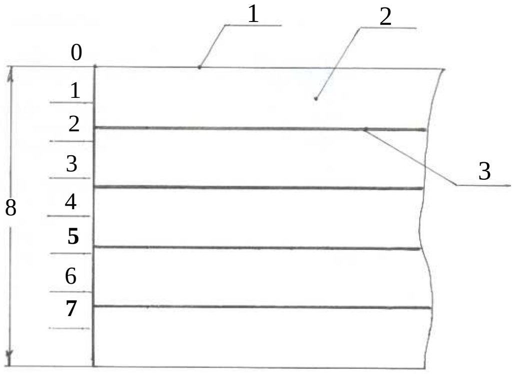

Fig. 3. Package diagram printed circuit boards of 5 plates: 1 – copper foil, 2 – fiber, 3 – double layer of copper foil.

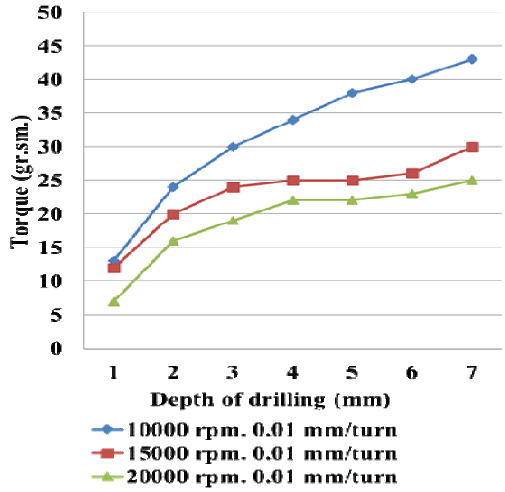

Fig. 4. The chart for standard drills $\omega = 30°$.

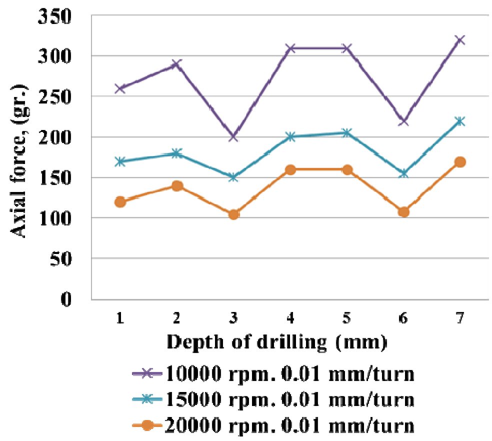

Fig. 5. The chart of axial efforts for standard drill $\omega = 30^0$.

The question is raised, what such growth of power indicators is caused to. Cutting conditions at the cutting edge of drills with increasing depth do not change. The only reason for this could be the increased contact area abrasive chips with the surface of the hole and emerged from its frictional forces.

It is necessary to note that sharp falling of axial effort on sites of depth 2–3 and 5–6 (see Fig. 5) it is caused by absence on these sites of the processed preparation (Fig. 3) copper layer. The main factor of increasing of probability of fragile destruction of the cutting tool from these two power indicators there cannot be the growth of axial effort, and more progressive increase in a torque as strength indicators of hard-alloy materials on compression considerably exceed indicators on torsion.

Accelerating the removal shaving 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 is solved in different ways. For example, when drilling by drills of the solid sizes it is carried out by a washing away method by means of lubricant cooling liquid, which moves in an opening via channels, executed in the body of a 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 periodically carried out by the fast course.

The application of these techniques in our case is not accepted. In the first we deal with microdrills. The use of coolant in the manufacture of printed circuit boards is not allowed. Also the method of intermittent drilling as it brought - to strong falling of productivity is inexpedient. 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 bring to a deterioration of the cutting conditions, so-as will decrease the cutting angle drills.

If to carry out a design of a drill in such a way that at top to keep the necessary forward corner, and in the direction of the end of a spiral flute to reduce its tilt angle, that is to cut a spiral flute with a variable corner and gradually to increase its step, it would lead to process acceleration shaving of removal and would facilitate drilling conditions.

Figure 6 shows the scheme of drills with vari-angle spiral grooves where the angle of the grooves at the top of the drill is 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 doesn't 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 – $B_{T1} = \frac{B_n}{\cos\omega_1}$.

Also the useful face section of a drill changes. Useful section at 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 we consider that $\omega_0 > \omega_1$, it turns out that toward the end of the working part of the useful cross-section drills amplifies. That is such drills in comparison with the standard have to sustain the raised loadings.

Production of such drills is connected 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 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 [2–5].

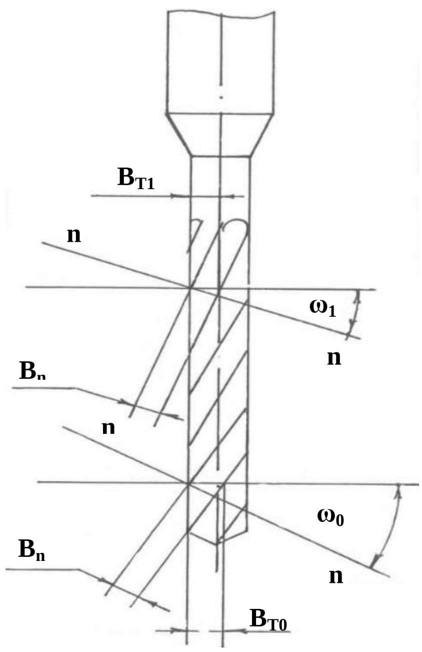

Fig. 6. Drill scheme with vari-angle spiral grooves.

Besides, because of a variable tilt angle of a spiral flute, at 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 around a point of intersection of these axes at a corner size $\omega = \omega_0 - \omega_1$ (see Fig. 7), or motionless to leave an axis of a spindle of preparation and to turn an axis of a grinding spindle (see Fig. 8) [7].

Proceeding from constructive reasons the preference was given by us to the first option (Fig. 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: $\omega_x = \ell_x \cdot K_\omega$, where ω_x – the current size of an angle of rotation of an axis of preparation, ℓ_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.

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

All of these included circuit boards same experiments as the standard. Experimental results for drills $\omega = 30 - 17°$ and $\omega = 35 - 20°$ are shown on Figs. 9–12.

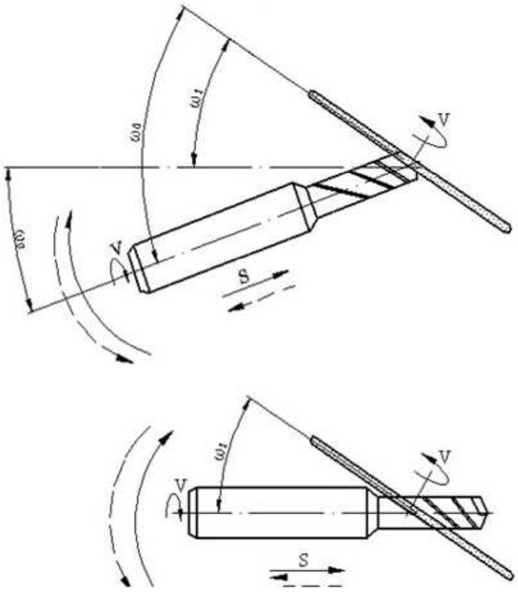

Fig. 7. Schemes of change of orientation of axes of a spindle of preparation of a drill and grinding spindle. Method of turn of an axis of a spindle of preparation.

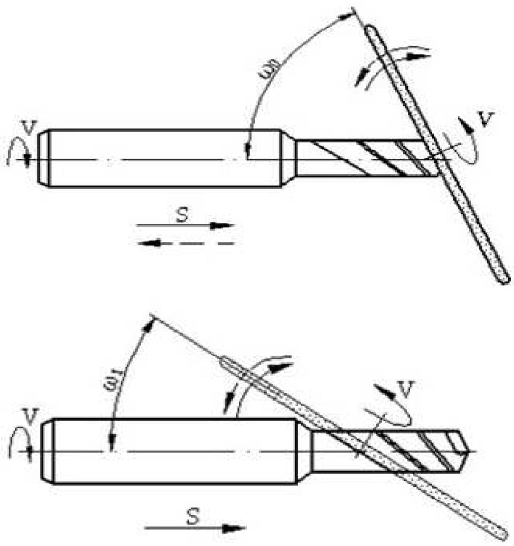

Fig. 8. Schemes of change of orientation of axes of a spindle of preparation of a drill and grinding spindle. Method of turn of a grinding spindle.

The analysis of these schedules shows the following: for drills $\omega = 30 - 17°$ indicators of axial effort almost don't differ from a standard drill $\omega = 30°$, it was expected, as at these drills an identical front corner and respectively, cutting conditions at the cutting edge. As for torque indicators, they on a drill depending on the modes of cutting are underestimated by 12–16%.

For drills $\omega = 35 - 20°$ 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 $\omega = 30 - 17°$ compared with standard drills $\omega = 30°$, due

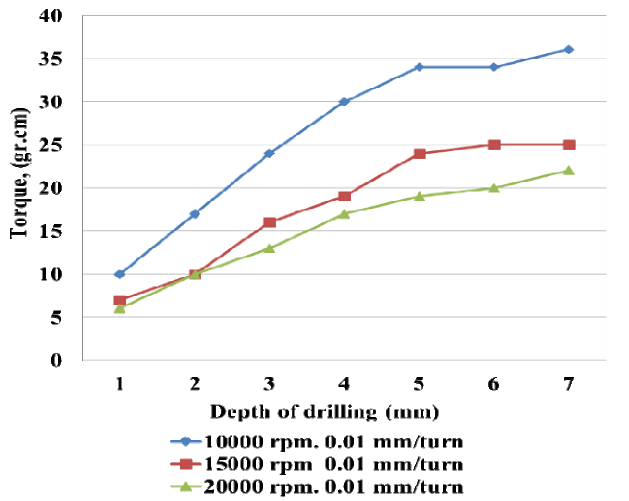

Fig. 9. The chart of change of a torque for drills $\omega = 30 - 17°$.

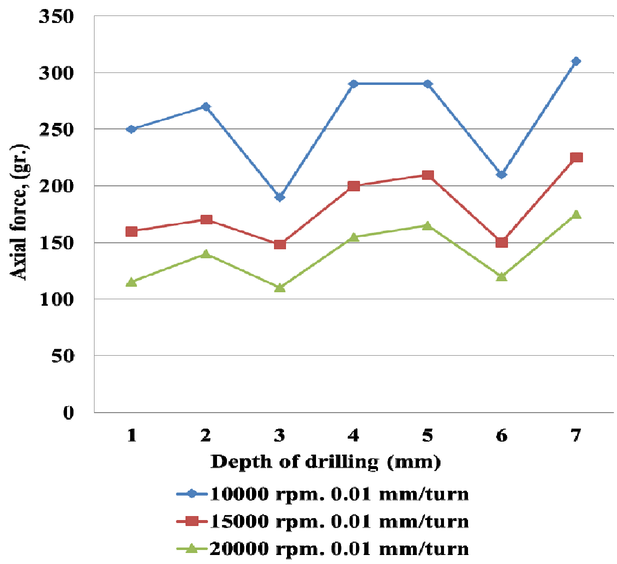

Fig. 10. The chart of changes of axial efforts for drills $\omega = 30 - 17°$.

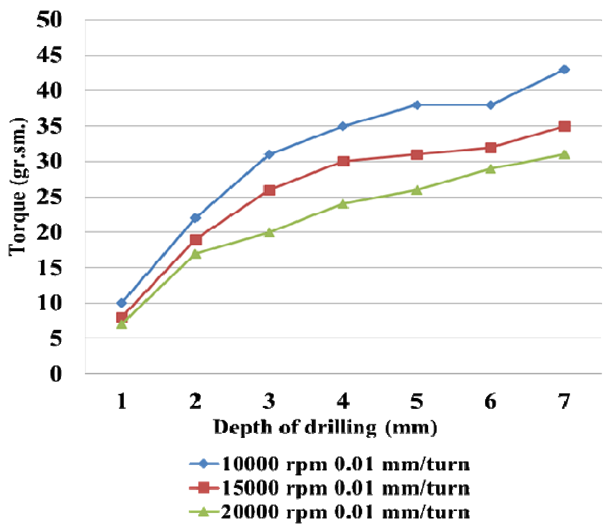

Fig. 11. The chart of torque for drills $\omega = 35 - 20°$.

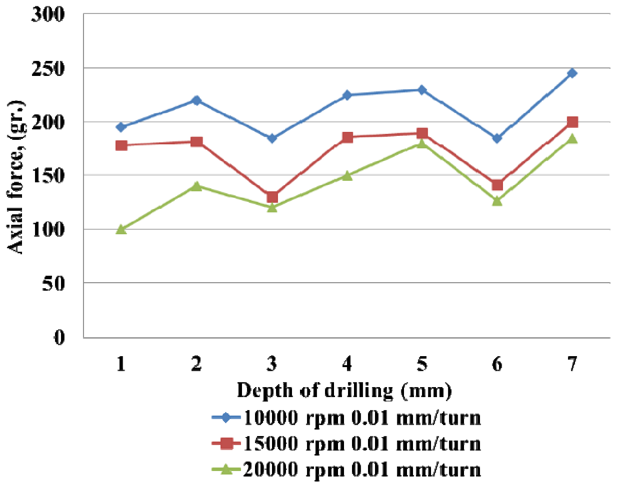

Fig. 12. The chart of changes of axial efforts for drills $\omega = 35 - 20°$.

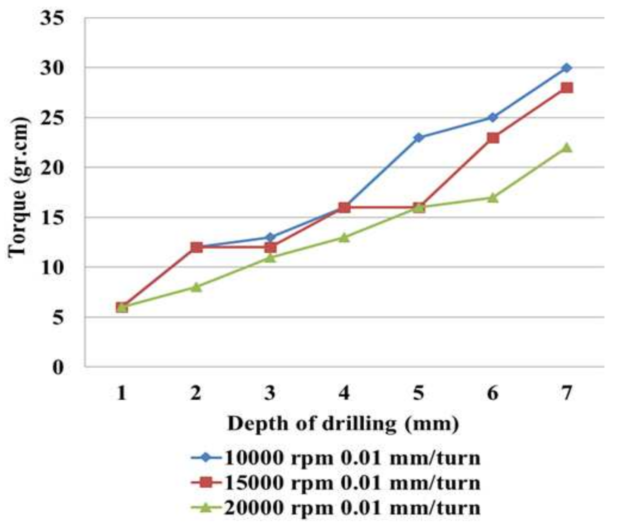

Fig. 13. The chart of change of a torque for a drill $\omega = 40 - 22°$.

to the gradual increase in step spiral grooves accordingly reduced contact area formed by chips with processed apertures. Increasing the angle of inclination and therefore a decrease in pitch of spiral drills $\omega = 35 - 20°$ again causes the return process – torque indicators intensively raise.

When drilling by drills of $\omega = 40 - 22°$ and $\omega = 43 - 23°$ these power indicators are rather underestimated (see Figs. 13–16) that is explained by improvement of conditions of cutting because of considerable (5–8°) 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.

Obviously, to get a clearer picture further experiment it is necessary to continue with standard drills $\omega = 30°$ and drills with vari-angle spiral grooves $\omega = 30 - 17°$. Experiments were continued until the breakage of drills. Thus through every the 200th opening power indicators which with increase in wear of the cutting edge gradually increase were checked. After 1000 openings, check was carried out through each 100 openings as the probability

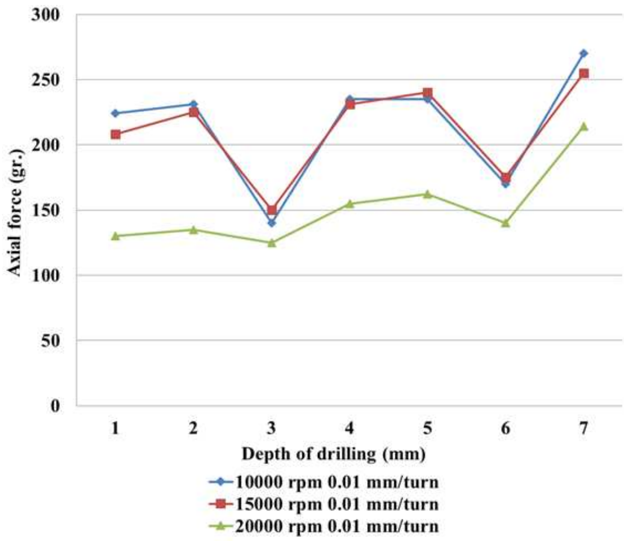

Fig. 14. The chart of change of axial effort for drills $\omega = 40 - 22°$.

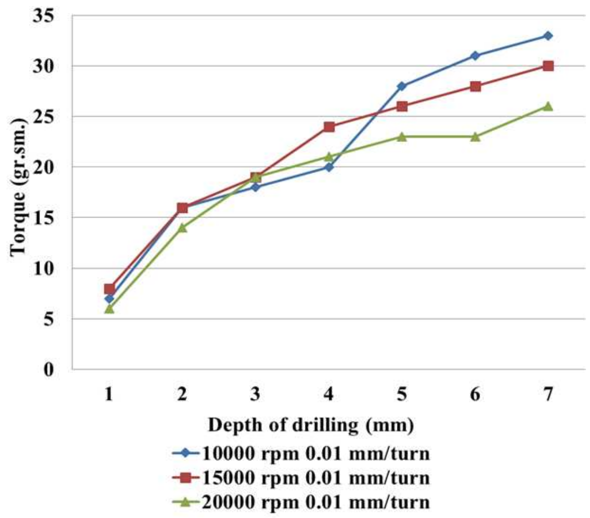

Fig. 15. The chart of change of a torque for drills $\omega = 43 - 23°$.

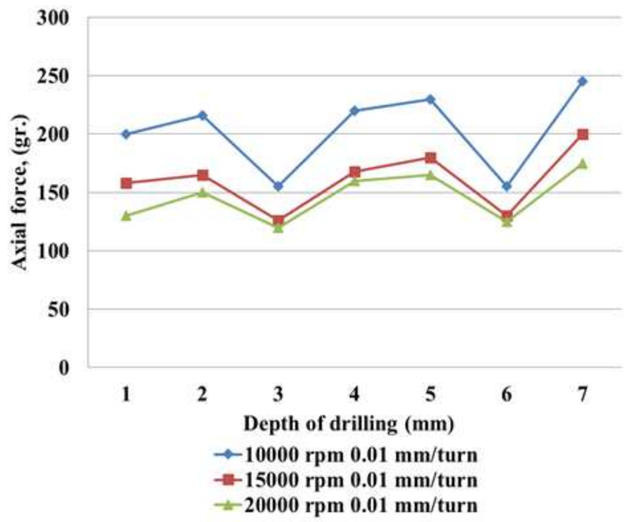

Fig. 16. The chart of change of axial effort for drills $\omega = 43 - 23°$.

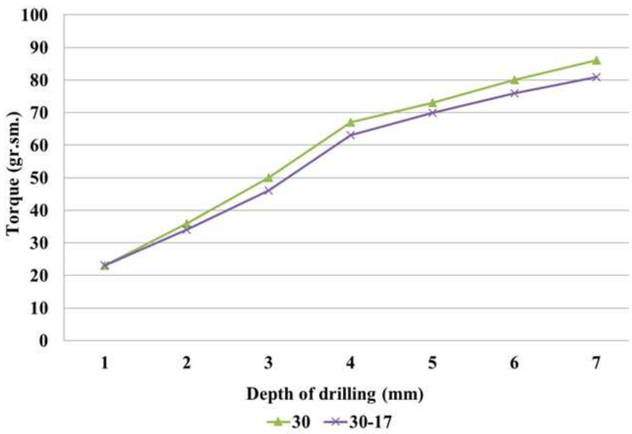

Fig. 17. The chart of torque graph for drills $\omega = 30°$ and $\omega = 30 - 17°$ before the breakdown drills $\omega = 30°$.

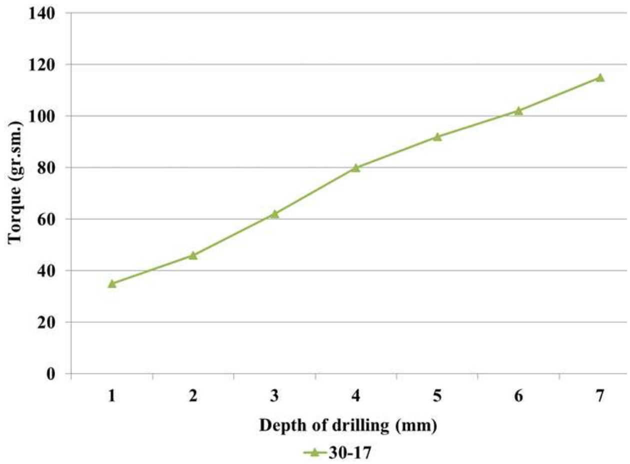

Fig. 18. The chart of change the torque diagram for drills $\omega = 30 - 17°$ before its breakdown.

of breakage of a drill increases. Throughout a series of experiments for both types of drills, $\omega = 30°$ almost identical were indicators of wear of the cutting edge and axial effort. As for torque, its value on the standard drills always exceed the value of drills with variable angle of the spiral grooves $\omega = 30 - 17°$.

The statistics showed that breakage of standard drills $\omega = 30^0$ happens from 1200 to 1300 openings, and drills to a variable corner $\omega = 30 - 17°$ from – 1400 to – 1500. Torque size indicators before breakage with the indication of quantity of the drilled openings of N passed ways of L and sizes of wear on a back surface of a drill off are shown on Fig. 17 and 18.

3. CONCLUSIONS

Solid Carbide micro drills with vari-angle spiral grooves in deep drilling package provides improved chip control process intensity of hole, promoting this underestimates the force of friction and consequently the torque on the axis of the drill.

Implementation of the spiral grooves with a gradual lowering of the ω-angle from the top of the drill toward the end of the working part provides useful cross-section reinforcement drills, increasing the reliability of the brittle.

On the basis of the foregoing, it becomes possible to manufacture drills with elongated working part at 2–2.5 mm and in the package circuit boards add another plate, which will make it possible to improve the performance of drilling process on 20%.

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