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Fast Drilling of Small-Diameter Holes by Core Flat Drills

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Abstract—Attention focuses on the fast drilling of small-diameter holes by core flat drills, hard-alloy drills, and unidirectional drills with the supply of working fluid to the cutting zone. Means of improving the productivity are discussed. The best approach to drilling small-diameter holes is outlined.

Keywords: high-speed drilling, core flat drill, unidirectional drill, hard-alloy plates, tubular housing, productivity, balance

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The use of hard-alloy drills to produce holes in steel and cast-iron components began in the middle of the last century, after the development of hard alloys. It was established that the efficiency may be increased by supplying working fluid to the cutting zone. The use of hard alloy and coolant considerably increases the possible cutting speed in comparison with high-speed steel tools [1–15]. The use of unidirectional drills generally proves successful.

Despite the extensive Russian and non-Russian research on the subject, no clear definition of high-speed drilling has yet been formulated. Therefore, in the present work, we offer an interpretation of this concept for two examples: machining by unidirectional drills; and machining by hard-alloy core flat drills. We employ the materials in handbooks [1, 2].

PRACTICAL EXAMPLES

High-Speed Drilling of Holes in Discharge Valves

High-speed drilling of 7-mm holes in discharge valves has been practiced at Chelyabinsk Automation and Mechanical Plant for more than fifty years. In that period, the plant has produced tens of millions of valves and gathered considerable experience in the high-speed drilling of small-diameter holes.

For a long time, the plant specialized in the production of valves and tappets for engines in Russian vehicles. Its products include the discharge valves for the ZIL-130 and GAZ-66 vehicles, in whose shafts deep holes are drilled for sodium cooling.

In Fig. 1, we show a valve in the course of hole drilling, after the formation of the complex section. The drilling process must satisfy three main requirements: a tolerance of 0.3 mm on the diameter; fluctuation in wall thickness no greater than 0.2 mm over the length of the hole; and surface roughness $R_a = 2.5$.

Particular difficulties were encountered on introducing the drilling of deep holes ($L/d \approx 11$, where L is the length and d is the diameter of the hole). Various approaches were tried. High-speed steel drills and drills with hard-alloy cutting plates proved too slow, on account of the need for frequent drill removal to permit cooling and chip extraction. In addition, the drills were not durable and frequently jammed and broke in the holes. The rejection rate of the valves was high on account of drill fracture and excessive fluctuation in the wall thickness.

The productivity was somewhat higher when using unidirectional drills (gun drills), and the fluctuation in wall thickness was within acceptable limits.

However, these processes did not ensure the required productivity and frequent drill fracture was observed. In addition, gun drills are expensive and difficult to manufacture. The best results were obtained in fast drilling by tubular drills: high productivity, compliance with all the technological requirements, and relatively high drill durability with relatively little manufacturing complexity.

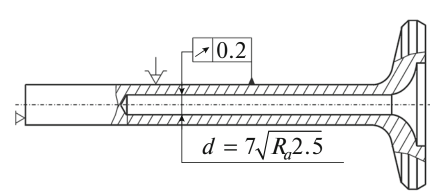

Fig. 1. Diagram of a valve during deep-hole drilling.

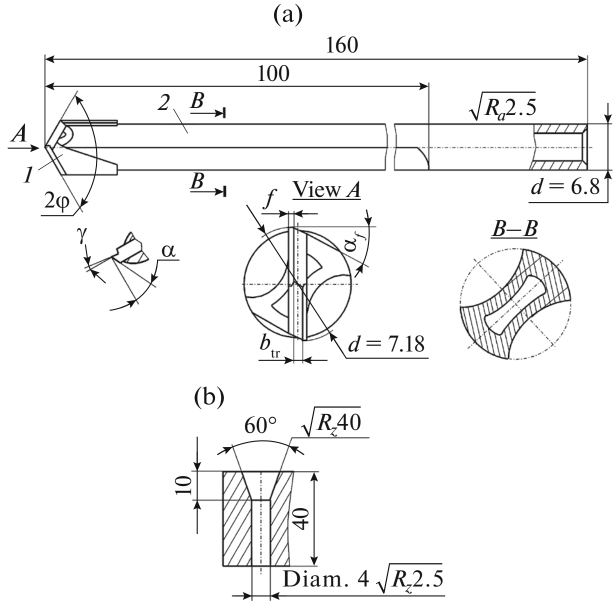

Fig. 2. Core flat drill (diameter 7 mm) produced at Chelyabinsk Automation and Mechanical Plant (a); and stepped hole (b): (*1*) carbide cutting insert; (*2*) tubular housing; 2φ, cutting edge angle; α, back angle; γ, rake angle; *f*, width of tracer edge; b_{tr}, thickness of cross-cutting edge; α_f, secondary angle.

Core flat drills manufactured in the tool shop at Chelyabinsk Automation and Mechanical Plant are now used in valve manufacture (Fig. 2a).

Deep holes in the valves are produced by means of core flat drills at relatively high cutting speed (v = 99.5 m/min) with relatively small supply (s_t = 0.027 mm/turn). That ensures high productivity (supply velocity v_s = 122 mm/min).

Fast Drilling of Stepped Holes

The fast drilling of small-diameter holes is used in the production of stepped holes consisting of conical and cylindrical sections (Fig. 2b). The housing in which the holes are drilled is made of 40X steel (hardness 28–39 HRC_e).

Strict requirements are imposed on the precision and surface quality of the holes. Accordingly, the process employed at Chelyabinsk Automation and Mechanical Plant calls for the drilling of such holes in five passes: three passes for the cylindrical section (drilling, countersinking, and reaming); and two passes for the conical section (rough and final countersinking). In all the passes, high-speed steel tools are employed. The countersinks and reamers are made in the plant's tool shop.

The production technology used for the stepped holes is slow and rapidly consumes cutting tools. To eliminate these problems, we investigate fast drilling of such holes by tubular drills with hard-alloy cutters, in the presence of working fluid. The results are of practical value.

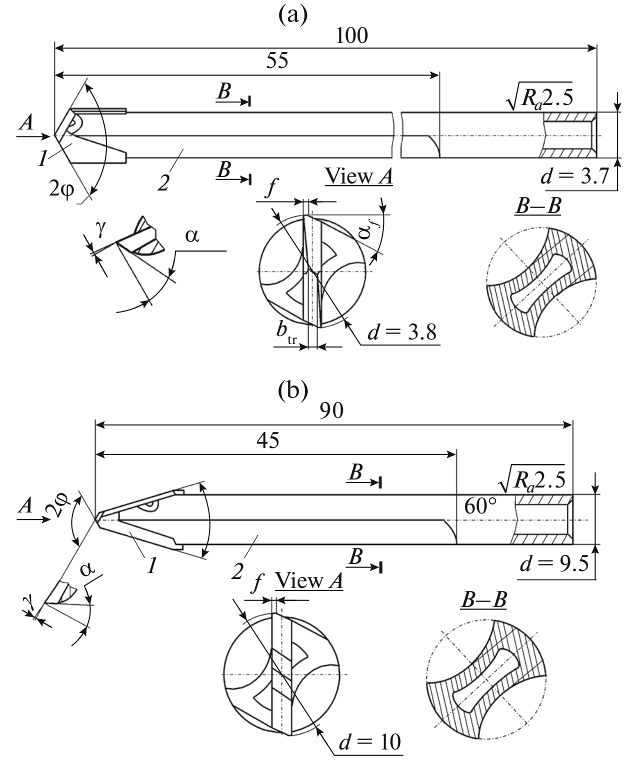

Fig. 3. Core flat drills of diameter 3.8 mm (a) and 10 mm (b): (*1*) carbide cutting insert; (*2*) tubular housing; 2φ, cutting edge angle; α, back angle of cylindrical section; γ, rake angle of cylindrical section; *f*, width of tracer edge; b_{tr}, thickness of cross-cutting edge; α_f, secondary angle.

Fast Drilling of Cylindrical and Special Conical Holes

Tubular drills (diameter 3.8 and 10 mm) produced at South Ural State University and in the tool shop at Chelyabinsk Automation and Mechanical Plant may be used the fast drilling of cylindrical and special conical holes (Fig. 3).

ANALYSIS

Analysis of the results obtained in the fast drilling of small-diameter holes (up to 10 mm) by core flat drills, with the supply of working fluid to the cutting zone, shows that this technology significantly increases the productivity and the tool life and reduces drill consumption.

On that basis, we may assess the prospects for the fast drilling of small-diameter holes by core flat drills.

We know that the basic characteristic of any industrial process is its productivity [1, 2, 15]. For drilling, the productivity may be assessed in terms of the supply velocity $v_s = n_s = 0.785\ (1000/d)\, v_s$. If the drill diameter d = const, the supply velocity is a function of two variables: (1) the cutting speed v; (2) the supply s. Their product may be regarded as the productivity R

$$R = vs. \quad (1)$$

The function in Eq. (1) has the dimensions of area/time and characterizes the removal of a particular area of material from a machined hole of constant diameter in unit time. It is clear from Eq. (1) that the productivity in drilling may be increased by three methods:

(1) increasing the cutting speed;

(2) increasing the supply;

(3) increasing both the cutting speed and the supply.

Method 1. The cutting speed plays a special role in drilling since it permits increase in productivity of the process with constant bit cross section. With constant bit cross section, the cutting forces will remain constant or increase only slightly. That is extremely important in machining small-diameter holes in view of the low strength and rigidity of the drilling system. In addition, we know that increasing the cutting speed will result in higher surface quality. Therefore, increasing the productivity by increasing the drilling speed merits special attention.

Method 2. The cross-sectional thickness of the cut is directly proportional to the supply (to half the supply in the case of tubular drills). With increase in cut thickness, the wear rate of the cutter increases, on account of increase in the mechanical and thermal load on unit length of the cutter. In addition, the surface quality of the hole declines with increase in the supply.

Method 3. In practice, increase in both the cutting speed and the supply is common. However, this method is of limited potential, since slight change in one of the parameters produces significant change in other parameters — for example, decrease in drill life or loss of surface quality. This indicates that the cutting speed and the supply are very closely related in drilling.

Analysis of Eq. (1) indicates that a certain balance exists in drilling (and other machining methods). Disruption of that balance has undesirable consequences, such as changes in the cutting forces, the onset of vibration, or temperature rise in the cutting zone. The balance will depend on the specific machining conditions (the drill design, the cutter material, the drilling fluid, the supply conditions, etc.).

Maintenance of the balance is the basis of any drilling process. As a first approximation, we may state the following condition: increase in the cutting speed must be accompanied by proportional (or near-proportional) decrease in the supply; and, conversely, increase in the supply must be accompanied by proportional decrease in the cutting speed.

The process is most effective with the best balance: that is, in conditions such that the best results are obtained—say, the required productivity—with the required drill life and surface quality. The concept of balance permits qualitative assessment of the drilling process.

Thus, drilling by helical bits is characterized by relatively low cutting speeds and large supply. Recommendations for this method have been developed on the basis of the standards in [1]. In standard conditions, balance is retained within permissible limits. With variation in some drilling conditions, correction coefficients are introduced so as to retain the balance. Limits on the balance have already been established for this method, and so research continues with a view to improving the process (primarily by improving the design of the drill and the cutter, without significant results).

Equipping helical drills with hard-alloy cutters tends to improve the balance of the process. However, efforts to improve the balance by increasing the cutting speed with unchanged (or slightly reduced) supply rarely have successful outcomes (especially when drilling steel). Thus, the cutting conditions remain practically at the same level as when using helical stainless-steel drills with qualitative change in the machining conditions—in other words, with the introduction of hard-alloy cutters.

The methods of drilling by means of hard-alloy gun drills and by means of tubular drills with the supply of working fluid to the cutting zone are characterized by a different combination: relatively high cutting speed and low supply. That corresponds to excellent balance. For these methods, recommendations have been made in terms of the cutting conditions and appropriate correction coefficients [1].

For these methods, experimental refinement of the cutting conditions is recommended for each specific case, so as to identify the best balance. This may be explained in that the combination of drilling conditions employed is very sensitive to slight changes.

On the basis of the balance, we may make the following distinctions:

(1) between low-power and high-power drilling, in terms of the supply;

(2) between low-speed and fast drilling, in terms of the cutting speed.

Accordingly, all drilling methods may be divided into two groups.

(1) Drilling at low speed with large supply. The supply plays the dominant role. Correspondingly, chip of large cross section is removed and the cutting forces are high.

(2) Drilling at high speed with small supply. The cutting speed plays the dominant role. Correspondingly, chip of small cross section is removed and the cutting forces are low.

In drilling small-diameter holes, small cutting forces are preferable (for the reasons already noted).

That corresponds to high-speed drilling with the required productivity and other characteristics of the process.

REFERENCES

1. *Obshchemashinostroitel'nye rezhimy rezaniya: spravochnik (General Machine Engeneering Modes of Cutting: Handbook)*, Moscow: Mashinostroenie, 1991, vol. 1.
2. Guzeev, V.I., Batuev, V.A., and Surkov, I.V., *Rezhimy dezaniya dlya tokarnykh i frezerno-rastochnykh stankov s chislovym programnym upravleniem. Spravochnik (Cutting Regimes for Turning and Milling-Boring Machines with CNC: Handbook)*, Moscow: Mashinostroenie, 2005.
3. Pămîntaš, E., Turc, G.C., and Banciu, F.V., Aluminum high speed drilling—some technological aspects, *Solid State Phenom.*, 2014, vol. 216, pp. 294–297.
4. Astanin, V.N., Tubular arrow-headed drills and their production technologies, *Stanki Instrum.*, 1964, no. 7, pp. 43–44.
5. Eberius, K., Deephole drilling process, *Cutting Tool Eng.*, 1980, vol. 32, nos. 5–6, pp. 5, 7–8, 10.
6. Kozochkin, M.P., Sabirov, F.S., and Frolov, A.N., Dynamic phenomena in deep drilling, *Russ. Eng. Res.*, 2012, vol. 32, no. 1, pp 108–110.
7. Flegel, E., Deephole drilling machines and tools for economic drilling operations, *IPE Int., Ind. Prod. Eng.*, 1985, vol. 9, no. 2, pp. 22–28.
8. Myasnikov, Yu.I. and Pimenov, D.Yu., High-speed drilling of small-diameter holes by core flat drills, *Russ. Eng. Res.*, 2016, vol. 36, no. 10, pp. 879–882.
9. Andryushchenko, A.I. and Serebrenitskii, P.P., The ejector drilling of deep holes, *Metalloobrabotka*, 2013, no. 1 (73), pp. 2–11.
10. Ariffin, M.K.A., Che Hussain, H.B., Mohammed, S.B., and Sulaiman, S., Determining optimum electro discharge machining parameters for drilling of a small hole by utilizing Taguchi method, *Appl. Mech. Mater.*, 2014, vol. 564, pp. 481–487.
11. Mikolajczyk, T., Olaru, A., and Krainski, P., Adaptive control system for drill machine, *Appl. Mech. Mater.*, 2013, vol. 436, pp. 445–450.
12. Ariffin, M.K.A., Che Hussain, H.B., Mohammed, S.B., and Sulaiman, S., Determining optimum electro discharge machining parameters for drilling of a small hole by utilizing taguchi method, *Appl. Mech. Mater.*, 2014, vol. 564, pp. 481–487.
13. Krishnaraj, V., Prabukarthi, A., Ramanathan, A., Elanghovan, N., Kumar, M.S., Zitoune, R., and Davim, J.P., Optimization of machining parameters at high speed drilling of carbon fiber reinforced plastic (CFRP) laminates, *Composites, Part B*, 2012, vol. 43, no. 4, pp. 1791–1799.
14. Ndaruhadi, P.Y.M.W., Sharif, S., and Kurniawan, D., Experiment investigation of hole accuracy and surface roughness in femur bone drilling using different parameters, *Adv. Mater. Res.*, 2014, vol. 845, pp. 720–723.
15. Tverskoi, M.M., *Avtomaticheskoe upravlenie rezhimami obrabotki detalei na stankakh (Automated Control of Operation Machine Regimes for the Parts)*, Moscow: Mashinostroenie, 1982.

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