ISSN 1068-798X, Russian Engineering Research, 2022, Vol. 42, No. 7, pp. 698–700. © Allerton Press, Inc., 2022.
Russian Text © The Author(s), 2022, published in Vestnik Mashinostroeniya, 2022, No. 4, pp. 78–81.

Broach for Cylindrical Holes and Slots

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Received September 17, 2021; revised September 30, 2021; accepted October 8, 2021

Abstract—The broaches proposed decrease the broaching force, vibration, and load on the tool tooth. That extends tool life, improves machining quality and productivity, and decreases machining costs.

Keywords: broach, durability, quality, effectiveness, productivity

DOI: 10.3103/S1068798X22070140

The development of progressive high-speed machining methods and technological processes is an important aspect of mechanical engineering. Broaching is a highly productive method, based on the simultaneous action of numerous cutting teeth. The efficiency of broaching is due to its high productivity and also to the strength and durability of the broach and its relatively short length, resulting in high shape and dimensional precision of the machined surface [1–4].

A broach is a multicutter tool, which usually moves linearly; rotary motion is much less common. A distinguishing feature of the broach teeth is that the height of each successive tooth increases, so that metal may be removed from a surface of any form [5, 6].

In broaching, surface precision IT 7–8 is possible, with surface roughness up to $Ra = 0.32$ μm [6].

In cutting, the chip is removed by each tooth at a rate of 2–15 m/min, as a rule, and passes through the trough between the teeth. Otherwise, the broach jams and may fracture [7–10].

The basic benefits of broaching are as follows: (1) high productivity, determined by the total length of the cutting edges involved in the process; (2) high machining quality (surface roughness up to $Ra = 0.32$ μm); (3) tool durability; (4) relatively simple equipment, with no need for high operator qualifications.

The deficiencies of broaching tools are as follows: the complexity of their manufacture and sharpening; high cost; narrow specialization; great length and relatively small cross section; and the impossibility of producing a hole that does not pass completely through the workpiece [8, 11].

Research on the design of metal-cutting tools has been underway for several years in the department of machine building and standardization at Toraighyrov Pavlodar State University, in order to improve machining condition [12–15].

In the broaching of cylindrical holes, change in the number of teeth that are acting simultaneously results in abrupt change in the cutting force. Consequently, the stress–strain state of the system changes, and vibration appears, with increase in roughness and shape imprecision of the hole and decrease in broach life [16].

To improve machining quality, a more effective tool has been developed: a shaping tool with helical teeth of equal width (Fig. 1) [6]. This broach may be sharpened at the rear tooth surface. That increases the accuracy of the hole produced and decreases the roughness of the machined surface as a result of complete restoration of the original tool parameters.

The use of a broach with helical teeth of equal width ensures smooth operation and a constant number of teeth that act simultaneously, since sharpening increases the broach quality and life and decreases its operating costs [17].

On the basis of the results, we have developed a more progressive two-part broach for machining cylindrical holes [18]. This tool improves the machining conditions, and increases the productivity. It decreases the broaching force, the vibration, and the pressure on the tooth, while extending tool life and improving hole quality — that is, the surface roughness and precision (Fig. 2).

The broach has a two-part cutting section, with teeth whose height increases successively over the cut-layer thickness. It is intended for margin removal. The cutting teeth in the first section have slotted straight-sided cutting projections for chip fragmentation. That

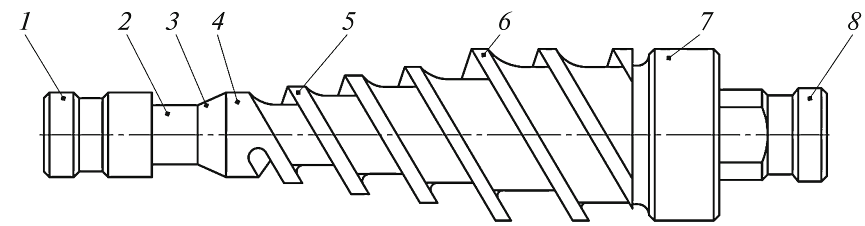

Fig. 1. Broach with helical teeth of equal width: (*1*, *8*) front and rear shafts; (*2*) neck; (*3*) conical adapter; (*4*, *7*) front and rear guides; (*5*) cutting section; (*6*) calibration section.

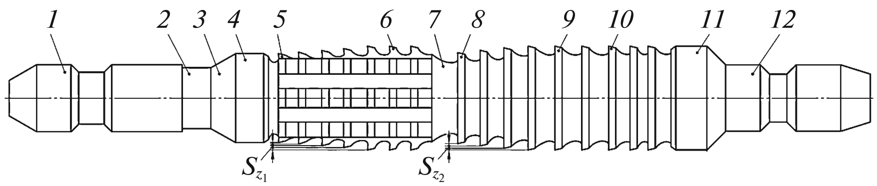

Fig. 2. Two-part progressive broach: (*1*, *12*) front and rear shafts; (*2*) neck; (*3*) conical adapter; (*4*, *11*) front and rear guides; (*5*) cutting section with straight-sided slotted projections; (*6*, *9*) preliminary calibration teeth in first and second sections, respectively; (*7*) transition region; (*8*, *10*) circular cutting and calibrating teeth; S_{z1}, S_{z2}, supply per tooth in first and second sections, respectively.

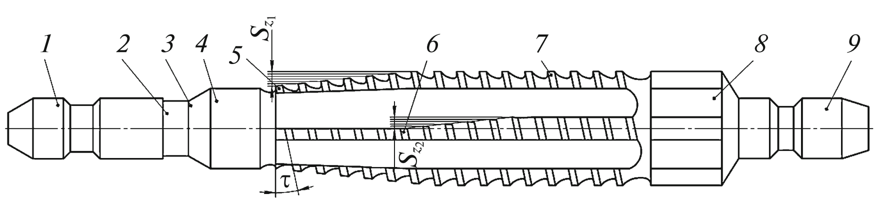

Fig. 3. Two-part slotting broach: (*1*, *9*) front and rear shafts; (*2*) neck; (*3*) conical adapter; (*4*, *8*) front and rear guides; (*5*) first cutting section (at tooth periphery); (*6*) second section, for machining slot sides; (*7*) calibration section; τ, inclination; S_{z1}, S_{z2}, supply per tooth in first and second sections, respectively.

increases the range of tooth supply and hence the productivity. The circular cutting teeth in the second section remove the projections between the channels formed by the first section.

In the calibration section of the broach, the calibrating teeth are preceded by two preliminary teeth to ensure the final dimensions and required precision and roughness of the machined surface. Beyond the preliminary teeth, the transition region between the first and second sections is increased to permit tool exit when milling and grinding the sides of the cutting projections. The broach is relatively simple and also easy to manufacture, since there is no need to machine recesses on the broach teeth, as in variable cutting [19].

The use of the two-part broach for machining cylindrical holes increases productivity and decreases the broaching force, the vibration, and the pressure on the tooth, thereby extending tool life and improving hole quality [19].

Taking advantage of the improvement in machining conditions and hole quality that is possible with progressive tool designs, we have developed a more efficient design: a two-part broach for machining slots with a straight-sided profile (Fig. 3). This broach is based on one-time cutting, with peripheral and lateral components. It operates as follows. The first cutting section produces narrow channels along the generatrix of the cylindrical hole; their width is approximately half the height (width) of the slotted projections. The second section expands the channels to the width of the troughs between the slots. The decreased width of the tooth's cutting projection permits increase in the supply per tooth to that in the first step. In terms of chip fracture, the second section resembles the generator configuration with increased supply per teeth [20].

The proposed slotting broach has fewer teeth and is shorter, with corresponding decrease in cost of the materials required and increase in economic efficiency [21].

Thus, the proposed broaches permit increase in machining productivity and decrease in the broaching force and vibration and also in the pressure on the tooth, while extending tool life and improving hole quality. They decrease the cost of the materials required and increase the overall economic efficiency.

FUNDING

Financial support was provided by the science committee of the Ministry of Education and Science of the Republic of Kazakhstan for the assistance of young scientists (2021–2023) within project IRN AR09058231 (regarding the research and design of resource- and energy-efficient metal-cutting tools), as part of program 217 (development of science) and subprogram 102 (research grants).

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Translated by B. Gilbert