Tools with rotary cutting edges – classification and terminology

Narzędzia z obrotowymi krawędziami skrawającymi – klasyfikacja i terminologia

JANUSZ CIELOSZYK
BOLESŁAW FABISIAK*

DOI: https://doi.org/10.17814/mechanik.2017.8-9.100

Research focuses on unconventional tools with the rotary edges (RET – rotary edges tools) type self-propelled rotary edges tool (SPRET) and driven rotary edges tools (DRET). Based on the analysis, corrected terminology and classification are presented.
KEYWORDS: rotary edges tools, SPRET, DRET

In recent years, in the most technologically advanced countries, the concept of machining with variable active cutting edge has been successfully returned, especially in the field of hard-working materials [1-4]. In the case of processes of processing such materials using traditional methods, there are many difficulties. These tools have a specified number of cutting edges (e.g. 3, 4, 6, 8 or 12), unchanged during cutting (fig.1a and fig. 1b).

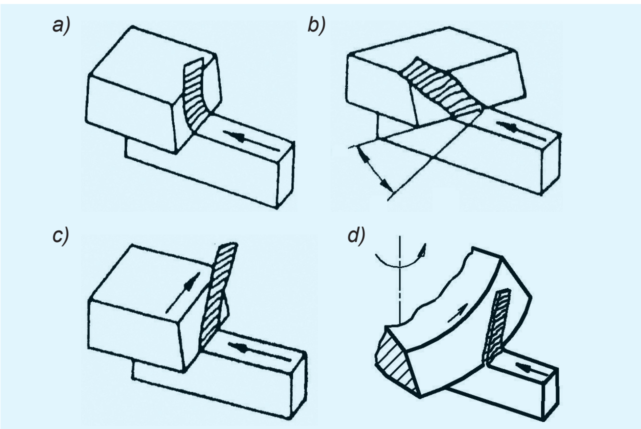


Fig. 1. Cutting variations with invariant edge: orthogonal (a) and oblique (b); cutting with variable active cutting edge: straight (c) and rotary (d)

In the case of cutting with the active cutting edge, the successive cutting edge cuts into the machining zone continuously throughout the cutting process until it reaches the dull state – in the case of a single cutting edge it is equivalent to its cutting edge and, in the case of a two-sided insert, double durability. The machining process thus accomplished can thus be defined as a machining with a variable active cutting edge (fig. 1c and fig. 1d). For this type of tooling and tooling, two factors are characteristic: a circular insert, used in all cases irrespective of the manner and type of machining, and its rotation (fig. 2).

The creator of the tool with rotating cutting edges is considered James Napier [10]. There are not any of its projects or constructions, but in 1868. Foresaw in his writings and presented enormous opportunities such tools in industrial applications.

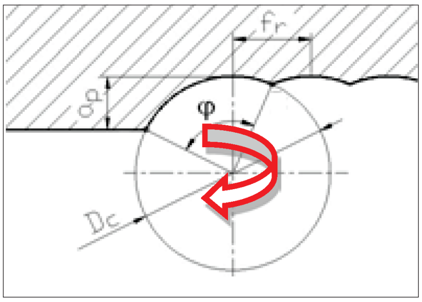


Fig. 2. Active cutting edge

The classification of these tools, which would adequately reflect the current state of their development and applications, does not exist. Thus, as a result of own research [1, 2], it was proposed to study the literature of the subject and the patents [3-9] and introduce the systematics of the construction of these tools and their applications. This seems justified also in the context of their historical development. Initially they have been used as special tools, and in recent years they have become commercially viable.

Rotary tools or tools with rotary edges?

In studies of experimental and industrial practice, these tools are often referred to as turning tools and the processes of their use – Treatment of rotating tools. This is mainly due to the simple scientific translation of publications, patent descriptions and implementation drawings. For example, in Russian, these terms are: ротационное резание, ротационное инструменты, and in English: rotary tools (RT), rotary cutting [4-6]. The most popular tool group with rotary edges is the lathe tool, which traditionally implements non-rotational movement (Table I). Their name in English and self-propelled rotary tools (SPRT) would indicate that we are dealing with rotary tools. In fact, only the edge itself rotates due to the force caused by friction of the surface of the chip attack. This movement is possible thanks to various solutions bearing the cutting insert.

The need for a proper definition of these tools also arises from the need to simplify and speed up the search for content in catalogs, articles or patents available on the web. The use of rotary tools, rotary cutting, rotary cutting, ротационное резание or ротационное инструменты on the web search engine usually leads to content related to typical cutting processes and typical rotary cutting tools such as milling cutters, drills

* Dr hab. inż. Janusz Cieloszyk (janusz.cieloszyk@zut.edu.pl), dr inż. Bolesław Fabisiak – Instytut Technologii Mechanicznej, Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

and reamers. It seems that the more precise name is: tools with rotary / rotary edges. In English the names and acronyms are: rotary cutting edge tools – RCET, rotary edge tools – RET, tools with rotary cutting edge – TRCE. However, in the English-speaking literature (e.g. in Japan, China, Korea, USA) there is a simplified, imperfect shortcut RT (rotary tools), although the more readable would be the rotary edge tools (RET) or RE (rotary edge).

Classification of tools with rotary edges

A general distinguishing feature of rotary blade tools (Table I) is the mechanism for obtaining the rotation of the cutting insert. Rotation of the plate in a kinematic embodiment shown in Fig. 1d can be obtained by the following methods:

- „automatic" rotation – under the influence of the forces acting during machining on the effective surface of the edge. Tools of this kind will be called self-propelled blade tools (SPRET) and self-propelled rotary edge tool (SPRET);
- forced rotation – by an external drive mechanism. Tools of this kind will be marked with DRET (driven rotary edges tool) or DRE.

A variant with periodic rotation of the plate is also possible outside the processing zone. This variant operably designated SPRET-Interrupt. Rotation of the plate would be carried out at intervals between the exit of the turning tool from a workpiece and the subsequent entry into the material (milling operations), or between each pass of the turning tool (in turning operations). The mechanism for periodic rotation of the plate can be constructed using commonly used media in machining, such as compressed air or high-pressure coolant (e.g., through a spindle milling machine).

The introduction of positive drive the insert (DRET) complicated and more expensive design tools, but allows for targeted control kinematic important parameter, namely the rotation of the cutting insert. The forced drive in DRET tools can improve some of the tooling effects [4-6] and is essential for geometrically complex machining, so that there may be an unstable rotation of the cutting insert. For technical and economic reasons DRET tools have been tested and used sporadically.

In all variants of the RET tools a rotary edge bearing is an essential element. The solution of the bearing node is a distinguishing feature of tools for bearing: sliding, sliding and mixed. While studying the development of these tools, one can clearly state that the problem of bearing was the main obstacle to their development. RET tool of the bearing system are under dynamically varying strengths, high temperature and often in an environment of the coolant, and various chip form. Ensure that the requirements concerning strength, thermal and chemical resistance, especially high geometrical accuracy (runout) of bearing and backlash-free, was and is a difficult task technically. An additional difficulty is the limited space in which the bearing node should be located. Tools or rotary cassettes that meet the requirements that are sufficiently met are now based on roller bearings that take degrees of freedom both in the radial and axial direction. Other embodiments of the bearings are only acceptable in the toolbar RET intended for the treatment of materials easily worked, non-metallic.

Recently, newly developed DRET edges designed for multi-axis CNC turning centers have opened up new perspectives [2, 8, 9]. Thus, there is the possibility of replacing a complex drive mechanism of the cutting insert, mounted in the body of each tool individually, the respective axis drive mechanism – CNC – modern machine tools.

TABLE I. Selected rotary edge tools (RET)

a)	SPRT turnig tool of Japanese Mitsubishi Carbide, right, type RRSDR3232P12. Replacement plates with diameter Np. – e.g. D_c = 12,7 mm, np. RDGH120400-M4 TF15	
b)	SPRT turnig tool of Japanese Mitsubishi Carbide, left, type RRS-DR3232P19. Replacement plates with diameter Np. – e.g. D_c = 19,05 mm, np. RNGJ190600-M5 US735	
c)	SPRT turnig tool of Rotary Technologies Corporation (USA) typu CLT-15RH with replaceable rotary cassette. Replacement plates with diameter Np. – e.g. D_c = 27 mm. Commercial tool appeared on the market in 2008	
d)	Custom designed SPRT, adapted for experimental testing with interchangeable rotary or stationary cartridges	

Tools with rotary edges driven by the machine spindle

This is a special group of DRET tools (called rotary front knives), in which there is no problem of difficult bearing of the cutting edge (fig. 3), and this simplifies the construction of both uniform tools (Table II (d)) and assembled.

The machining of these tools resembles the milling process. In both cases, the object and the tool perform a rotational motion, and in addition the tool or object performs a movement. However, there is a fundamental difference in surface shaping: the front edges characterizes the constant, continuous presence of the same edges in the material.

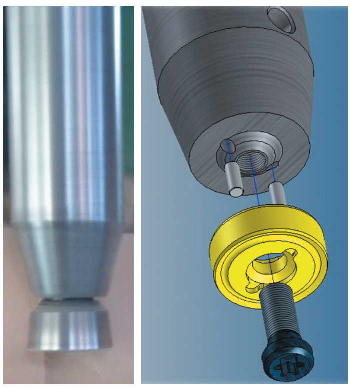
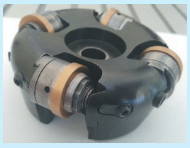
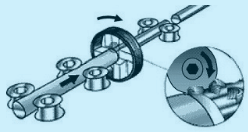


Fig. 3. DRET (driven rotary edge tool)

TABLE II. Single- and multi-edge tools with rotary edges (RET)

a)	SPRET C80-4 RTC cutter head (USA) with interchangeable rotary cassettes, also with the possibility of using an additional cassette with straight edge smoothing plate	
b)	SPRET drilling tool (by RTC, USA), made on special order	
c)	Pruning head with rotary cassettes in special versio	
d)	Custom built for use on multi-axis CNC turning lathes or special attachments for conventional machine tools. Version with geometry adapted for woodworking and other soft materials	

The proposed name of the turning tool is also acceptable in other languages. This is analogy to face milling – face rotary turning tools (FRTT).

In recent years, English-language literature [2,8,9] has been assigned an individual name for spinning-turning spinning tool technology. Both names may function in parallel also in Polish: FRTT or spinning. In the future, with the development of this technology and increasing the frequency and scope of its use, one can name one.

It should be emphasized that in the variant of the use of multi-axis CNC lathes, the tool can work both as SPRET and DRET. The only condition for changing from SPRET variant to DRET is that the spindle rotation resistance at the disengaged drive must be less than its torque due to the friction force of the chip on the rake surface. In addition, the frictional force can be increased or decreased by altering the angle of the tool axis.

Rotary edge tools for various types of machining

The basic distinguishing feature of rotating edge tools is the type of machining they are intended for. The RET tool constructs for the operation are:
- turning of external surfaces and ends (Table I, (a-c)),
- boring (Table I, (d)),
- milling (Table II (a))
- drilling (Table II (b))
- peeling (Table II (c)).

An important distinguishing feature of RET tools, characterized by their kinematic cutting properties, is the orientation of the cutting plate relative to the workpiece, defining the position of the rake surface, the application and the position of the axis of rotation of the plate. Fig. 4a and fig. 4b show the most common variants of the cutting inserts relative to the workpiece, differing by the angle of inclination of the cutting insert axis relative to the basic plane. Accepting the cone of the cone (or roller) as the railing surface lessens the space in which the bearing knot can be placed. This embodiment was used in the construction of the tools with large dimensions, constructed with the use of ball bearings. Variation of the cutting insert shown in fig. 4d (i.e. Frustum), currently being developed and tested in RTC company (USA), characterized by a more favorable discharge of chips from the cutting zone, and good strength of the edge.

a) b) c) d)

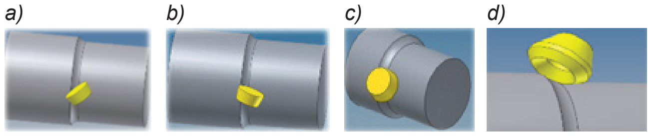


Fig. 4. Selected cutting plate positions relative to the workpiece: a-b) the rake surface is the base of the cone (or roller); c) the rake surface is the cone surface; d) the geometry of the cutting plate is called the frustum

Conclusions

The proposed terminology and classification is merely an attempt to systematize known (or possible) construction solutions for rotary cutting edge tools that are constantly being developed and improved.

Overview of structural solutions together with their characteristics can be a valuable inspiration for both tool builders and technologists planning to use these tools (RETs) in modern machining processes.

REFERENCES

1. Cieloszyk J., Zasada M. "The Self-Propelled Rotary Tools-Future Conception In Metal Cutting?". *The 15th DAAAM International Symposium Intelligent Manufacturing & Automation: Globalisation – Technology – Men – Nature*, 3–6th November 2004, Vienna, Austria, s. 075–077.
2. Cieloszyk J., Zasada M., Wieloch G. „Właściwości i perspektywy zastosowań aktywnie napędzanych noży obrotowych ADRT na wieloosiowych centrach obróbkowych". *Innovative Manufacturing Technology 2*. Ed.: Rusek P. Kraków: IZTW, 2012, ISBN 978-80-228-2385-2, s. 29–39.
3. Dessoly V., Melkote S.N., Lescalier C. "Modeling and verification of cutting tool temperatures in rotary tool turning of hardened steel". *International Journal of Machine Tools and Manufacture*. 44 (2004): s. 1463–1470.
4. Ezugwu E.O. "High speed machining of aero-engine alloys". *Journal of the Brazilian Society of Mechanical Sciences and Engineering, ABCM*. XXVI, 1 (2004): s. 532–539.
5. Ezugwu E.O. "Key improvements in the machining of difficult-to-cut aerospace superalloys". *International Journal of Machine Tools & Manufacture*. 45 (2005): s. 1353–1367.
6. Kishawy H.A., Becze C.E., Mcintosh G.G. "Tool performance and attainable surface quality during the machining of aerospace alloys using self-propelled rotary tools". *Journal of Materials Processing Technology*. 152 (2004): s. 266–271.
7. Kishawy H.A., Wilcox J. "Tool wear and chip formation during hard turning with self propelled rotary tools". *International Journal of Machine Tools & Manufacture*. 43 (2003): s. 433–439.
8. Nakajima K. et al. "Effect of rotary cutting tool posture on machining performance utilizing multi-tasking lathe". *Journal of Advanced Mechanical Design, Systems, and Manufacturing*. 2, 2 (2008): s. 532–539.
9. Sasahara H., Kato A. et al. "High-speed rotary cutting of difficult-to--cut materials on multi tasking lathe". *International Journal of Machine Tools and Manufacture*. 48, 7–8 (2008): s. 841–850.
10. Shaw M.C., Smith P.A., Cook N.H. "The rotary cutting tool". *Transactions of the ASME*. 1952, s. 1065–1076.