Cutting with diamond saw blades non-metallic materials

Przecinanie materiałów niemetalowych tarczą diamentową

BOŻENA CIAŁKOWSKA
MAGDALENA WIŚNIEWSKA*

DOI: https://doi.org/10.17814/mechanik.2017.4.48

The article presents a specificity of cutting with abrasive diamond blade saws. The types of blades considering construction are discussed. Also possibilities of the application of this method in relation to various, hard – machinable mostly nonmetallic materials are described. Paper presents advantages and limitations concerning different types of blades.

KEYWORDS: hard machinable materials, cutting, diamond saws

Cutting is one of the basic technological processes of manufacturing products. Depending on the technological requirements and the purpose of the shaped element, cutting may be the first operation preceding the further processing or the first and last, and thus may constitute a so-called *cutting finishing* [2]. Industry-specific material separation methods are accomplished by a number of loss-making techniques and by various tools. Each method has its distribution scope and field of application, in which its effects are technically and economically justified.

The development of cutting technology is driven by the pursuit of the most cost-effective use of specific tools, while maintaining high process efficiency. Commercially available machines and tools are characterized by high precision and repeatability of cutting effects. Cutting methods differ in the amount of energy consumed, cutting speed, material loss, temperature effect on the material to be cut, as well as the quality of the surfaces and edges obtained [7].

The need for processing of modern materials affects the continuous development of cutting technology. The choice of method depends on the requirements of the designer of the item and the technical capabilities, ie: the type and thickness of the cut material, the shape of the cut piece and the required shape accuracy, width of the heat affected zone and dimensional tolerances.

* Dr hab. inż. Bożena Ciałkowska prof. nadzw. PWr (bozena.cialkowska@pwr.edu.pl), dr inż. Magdalena Wiśniewska (m.wisniewska@pwr.edu.pl) – Wydział Mechaniczny Politechniki Wrocławskiej

Diamond discs

Diamond is widely used in industrial applications for over 70 years. The creator of these tools is considered a chemist and pharmacist Richard Felker. Around 1939,

Felker created the first abrasive blade, settling a mixture of diamond grains, metal powder and olive oil on a metal core [14-16]. This shield was used primarily for cutting stone. After a few modifications to these tools have started to be used for cutting concrete and quartz crystals and military industry [15].

Diamond discs have hundreds of varieties that differ in the type of core and binder, bonding technique or abrasive placement. These abrasive tools are used to cut different types of materials, such as natural stones, monocrystals, glass, ceramics, concrete and many others. Regardless of the variant and the use of diamond, wheels are constructed from a metal body, the periphery of which (external or internal) is submerged in the layer of diamond metal bond (fig. 1).

Fig. 1. The idea of forming an abrasive diamond disc [14]

How to prepare this type of tool? Generally, the process can be divided into the steps of:

- preparing and mixing raw materials,
- cold (or hot) pressing,
- sintering,
- joining elements with diamond body,
- machining [1, 6, 9].

Usually, powder metallurgy is used for bonding the diamond. An alternative method is galvanic deposition of the matrix metal. The matrix material in the metallic-diamond tools can be cobalt powders, as well as cobalt with iron, copper, bronze or nickel [9]. During the

diamond sanding process, the diamond crystals are positioned in a directional manner so as to obtain optimum cutting quality. In order to combine diamond segments and discs with body material, two methods are most commonly used today: soldering and laser welding [1, 17]. The choice of joining method depends on the purpose of the tool and the pressures exerted in the workpiece - tool system. In the case of tools used in the processing of wet segments are subjected to brazing. The use of such tools for dry working could cause the weld to weaken as a result of the temperature that occurs during the cutting and even the separation of the segments. Laser welding is used instead in the manufacture of tools for dry [5, 9].

Because of the spectrum of varieties and thus the wide use of diamond discs, there are different divisions of these tools. Considering the slope position of the abrasive discs stand out from the outer cutting edge and cutting the inner circumference. The diamond layer can be applied continuously or in a segmented form, with or without slits in the body (Figure 2). The discs can be designed for dry or wet work, for cutting hard, brittle and soft materials of different structure and thickness [21]. Sample solutions for a structure discs and the outer circumference shown in fig. 2.

Diamond wheels cutting with the inner circumference have a continuous embankment (fig. 3). This is due to the thickness of the body and a completely different method of fixing this target group (as explained later in this paper).

Depending on the intended disc, appropriate particle size diamond powder and its orientation, concentration and type of adhesive binding is selected [5]. Cutting discs - the inner or outer circumference - are in the same range of diameters, i.e. from approximately 120 to 900 μm [12, 20]. The cutting speed depends on the rotation of the cutter shaft, the diameter and type of the diamond disc and the properties of the cut material - in the case of cutting discs, the internal circumference is in the range of 16 ÷ 20 m/s, and in the case of discs with external embankment - over twice.

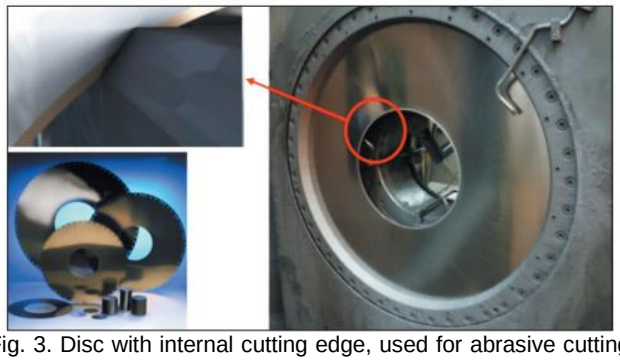

Fig. 3. Disc with internal cutting edge, used for abrasive cutting [13, 19]

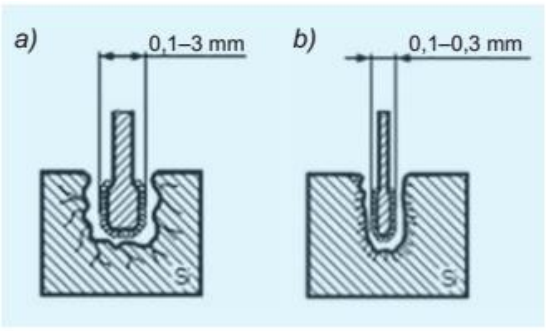

Fig. 4. Zone of damaged top layer for discs: *a)* cutting with outer circumference, *b)* cutting with inner circumference

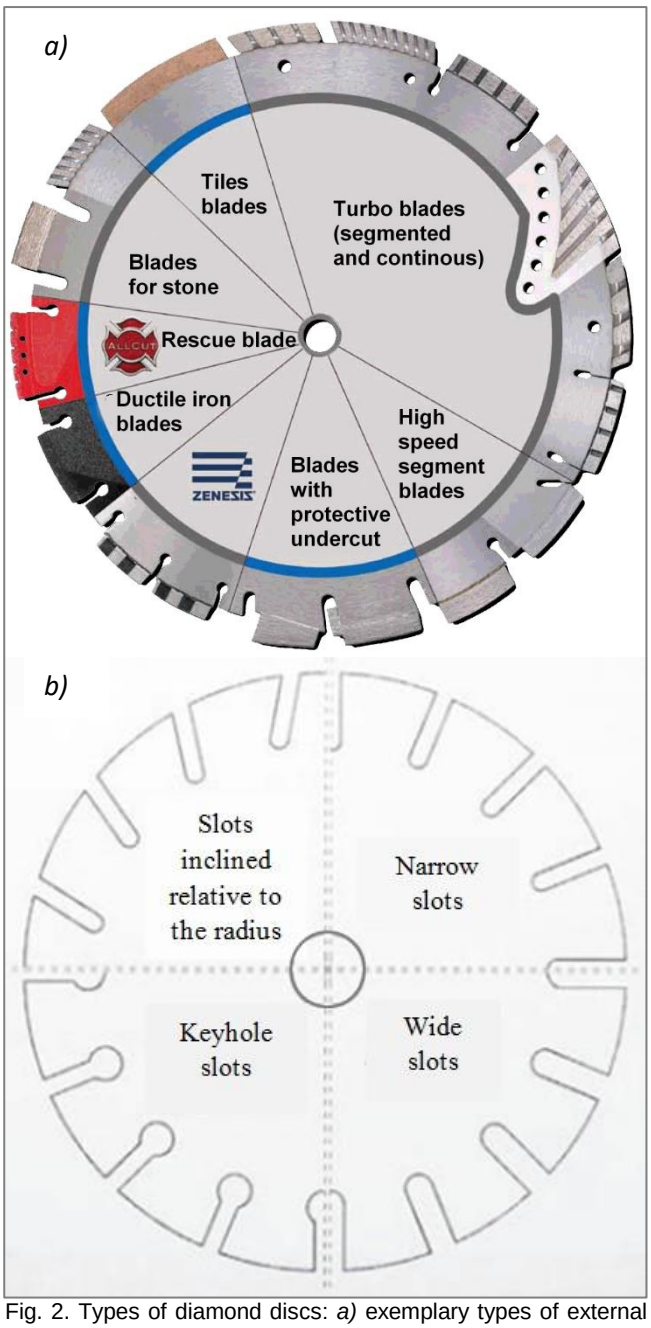

Fig. 2. Types of diamond discs: *a)* exemplary types of external cutting edges and area of use, *b)* basic types of cogs [5, 9, 18]

The decisive factors for the tool selection are the expected surface quality after cutting and the width of the cutting slit that affect the economics of the process. It should be noted that for cutting discs with internal circumference, the cut gap and the damage zone of the surface layer of the material are considerably smaller than those of the outer circumferential discs (fig. 4, [2]).

Surface roughness after cutting with diamond discs is closely related to grain size and its concentration and cutting parameters. For the inner circumferential discs, a Ra surface roughness of 0.1 μm can be obtained, while for discs with an outer cutting edge, this value can be up to several μm [3].

Cutting using disc with internal cutting edge

The disc with internal cutting edge is a tool manufactured similarly to the outer circumferential cutting discs. On the inside edge there is a multi-layer coating of galvanically bonded diamond microspheres. On its outer

perimeter, holes are provided to fix, tighten and center the tool in the head holder. The scheme of such tool is shown in fig. 5, and in fig. 6 - the essence of cutting with the inner cutting edge and its fixing system in the machine head.

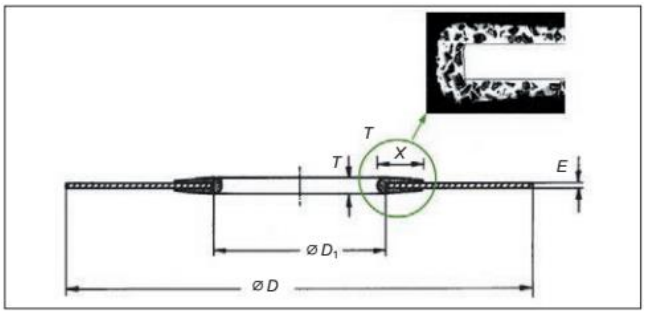

Fig. 5. Cross section of the diamond disc for cutting with inside edge: *D* - outer diameter, D_1 - inner diameter, *T* - cutting width, *X* - width of diamond, *E* - core thickness [12]

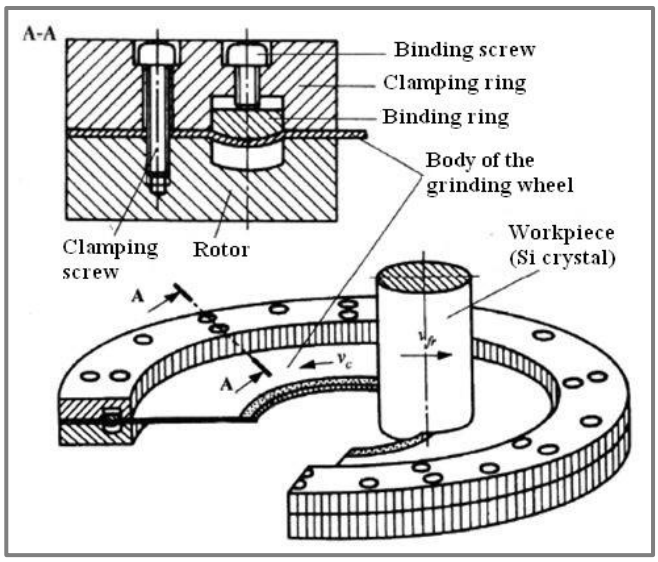

Fig. 6. Principle of fastening and cutting the workpiece inside the perimeter diamond blade [8]

Currently used in the industry discs have a thickness of 0.1 ÷ 0.2 mm, which makes them less stiff. In order to minimize this problem, the disc is fixed by radially distributed holes (fig. 6) and then evenly stretched to obtain the right rigidity of the tool [3, 4]. The area of application of these discs is primarily a precise cutting of optical components and electronics. Due to the very small cutting width, good surface quality, low damage zone and very good dimensional and shape accuracy, they are suitable for cutting single crystals of silicon, quartz, sapphire, glass and ceramics.

When cutting using diamond discs with an internal embankment, a number of important factors can cause errors in shape and surface roughness. Irregular flow of coolant, improper belt tensioning, and insufficiently rigid attachment of the cut can cause unequal forces, favoring bending of the blade and changes in the shape of the embankment [10, 11]. In addition, it should be borne in mind that along with the increasing number of intersections creep and relaxation of the disc material, which changes the shape of the elliptical hole and causes beating. It is also important that the ridge on the inner surface of the abrasive grain were, for exposure of the core may result in damage to the disc (cracks, bends) and damage to the cut material [3].

Cutting using disc with outer cutting edge

While the inner circumferential discs are used primarily to precisely cut expensive and delicate materials, the range of circular saw blades is very wide. Taking into account the fastening system of these discs, high rigidity is required from the body, which translates into the thickness of the disc. Depending on the operating conditions used saws have a different shape and size of the grooves (fig. 7). The teeth increase the flow of coolant in the tool contact area with the cut material and prolong the tool life. Selecting a particular type of disc is dictated by the properties of the material to be cut. Materials such as clinker, natural slate, ceramic tiles and building ceramics require the use of continuous-ring discs. In the case of marble, brick, sandstone and concrete, segment shields work well. Structural and structural materials used for the cutting of the outer rim cutting discs include reinforced concrete, asphalt, granite, marble, terrazzo, gres, laminates and others.

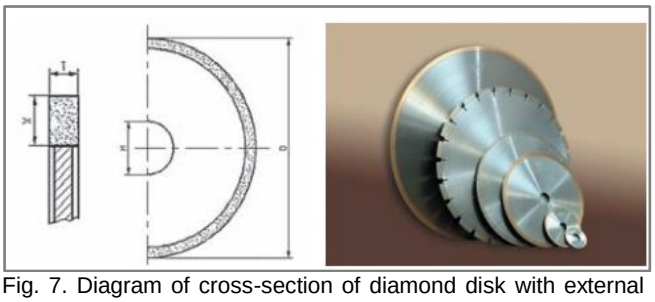

Fig. 7. Diagram of cross-section of diamond disk with external cutting circumference and sample tools of this group [20]

Diamond discs with an outer circumference are less susceptible to rupture of the body than discs with an internal abrasive grit. In this case, however, there are damages in connection with the temperature, which can promote the deformation of the body shield. Uneven wear of the segments is generally associated with a poor axial clamping of the disc. The most common error leading to destruction of the disc is the mismatch between design tools to cut material properties.

Conclusions

Diamond tools play an important role in shaping the products. Contemporary building and construction materials with high abrasion resistance require tools with the best cutting characteristics and high abrasion resistance. In the treatment of natural stone and crystalline semiconductor materials, precision and loss of material are important. Diamond wheels allow for very high dimensional accuracy and favorable condition of the surface layer of the workpiece with good process efficiency, so they are used in many industries. In this respect, few tools can compete with them.

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