IOP Conf. Series: Materials Science and Engineering **142** (2016) 012099 doi:10.1088/1757-899X/142/1/012099

Quality Estimation of Dry Grinding of Skiving Cutters With Organic Bonding Diamond Wheels

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Abstract. Engineering process preparation requires proper preparation of cutting tools. It influences not only the performance of the tools but also the quality of workpiece surface machining. One of the promising environmentally friendly trends of mechanical treatment is grinding without using lubricating cooling liquid. This method can considerably influence the quality of cutting tools grinding. Smoothing skiving turning is an effective treatment method providing high efficiency and workpiece quality. Proper preparation of cutting edges is especially important in this process. For that purpose we have carried out a research in grinding changeable carbide inserts for skiving turning by means of grinding wheels with different grain size. The influence of different combinations of wheels on roughness of the inserts front and rear surfaces and quality of cutting edge was studied with the help of laser confocal microscopy.

1. Introduction

Preparation of the tool surface and cutting edge is one of the key problems on the engineering process preparation [1-3]. It is generally known that providing proper preparation of the tools is an essential prerequisite of their effective application for machining operations [4, 5].

Machining without using lubricating cooling fluid called dry-cutting is one of ecologically-friendly machining methods [6, 7]. Alongside with dry cutting, dry grinding which is a process of grinding without lubricating cooling fluid attracts attention of researchers [8-12].

Skiving turning is a relatively new method of mechanical treatment which became spread due to a number of researches done in 70s-90s of the last century [13-16]. Based on these and some more recent works [17-20] we can determine a number of distinctive features of machining with skiving cutters which distinguish skiving turning from the conventional process (turning using a cutter with the tip):

1. Skiving cutters as they are called in [13-16] have no tip as a material body.
2. Bevel turning with a rectilinear skiving cutter produces one-sheeted hyperboloid of revolution while turning and boring with an elliptic skiving cutter provides a quartic surface [17-19].

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3. When in the process of bevel turning the edge of a skiving cutter is set at an angle (ω) to the workpiece rotation axis a wide range of cutting edge geometries along the working area of the cutting edge tip is produced [20].
4. Cross-cut section of the cut layer is characterized by cut layer thickness value much lower than cutting depth and feed while the same parameters of the cut layer width are much greater. Values of cross-cut section parameters depend not only on the feed, cutting depth and cutting edge shape but also on the workpiece diameter and the edge inclination angle [17-19].

The differences between skiving and conventional cutting identified above as well as the experimental research previously done [17-20] prove the necessity to carry out proper preparation of the cutting edge of a skiving cutter providing minimal possible radius of cutting edge tip round-off. The latest factor is greatly determined by the fact that when skiving cutters are used for finishing operations the cut-off layer has to be of a small width. The width of the cut-off layer is changes from zero at contact boundary of the tip with the workpiece to some maximum value which also does not exceed some tens of microns.

The aim of this research is to determine conditions for proper preparation of cutting edge tip of changeable carbide inserts used for skiving by means of grinding by diamond wheels with different grain size without treatment with lubricating cooling liquid.

2. Methods of research

Triangle inserts TNMG-160408 M2 of AP10AT alloy were used for the research. Grinding of changeable carbide inserts was carried out on universal tool grinder 3E642E using dish-shaped diamond wheels 5-0013 12A2-20 150-18-6-2-32 with organic bond B2-01 with 100% concentration of diamond powder AC4, AC6, ACH and grain size 100/80, 80/63 and 40/28 accordingly. Grinding powders AC4, AC6 are made of synthetic diamonds in which grains are separate crystals with developed surface, aggregates and crystal-jams. Micropowder ACH is made up of synthetic diamonds with high abrasive power. Organic bond B2-01 was chosen because it allows producing high quality grinding of carbide tools without treatment with lubricating cooling substance. Spindle revolutions per minute are 3,150. Table 1 shows feed values in rough finishing and smoothing grinding.

Grinding was carried out on the front and rear surfaces of changeable carbide inserts. Different combination of diamond wheels were applied in the process: the 1st wheel for rough grinding; the 1st and the 2^{d} wheels for rough grinding followed by finishing operation; the 1st, the 2^{d} wheels and the 3^{d} wheels for successive rough, finishing and smoothing grinding; the 1st and the 3^{d} wheels for rough and smoothing grinding. The latest combination is tested to analyze ways of make the grinding process more efficient.

Table 1. Feed values in grinding changeable carbide inserts

Machining operation	longitudinal feed, mm/double pass	longitudinal feed, m/min
Rough	0.03	1.0
Finishing	0.02	0.25
Smoothing	0.01	0.2

Figure 1 (a) shows a scheme of scanning of the grinded cutting edge of a changeable carbide insert for the skiving cutter performed with the help of 3D laser confocal microscope Olympus LEXT OLS 4100. Fig 1(b) shows an optical image of the insert.

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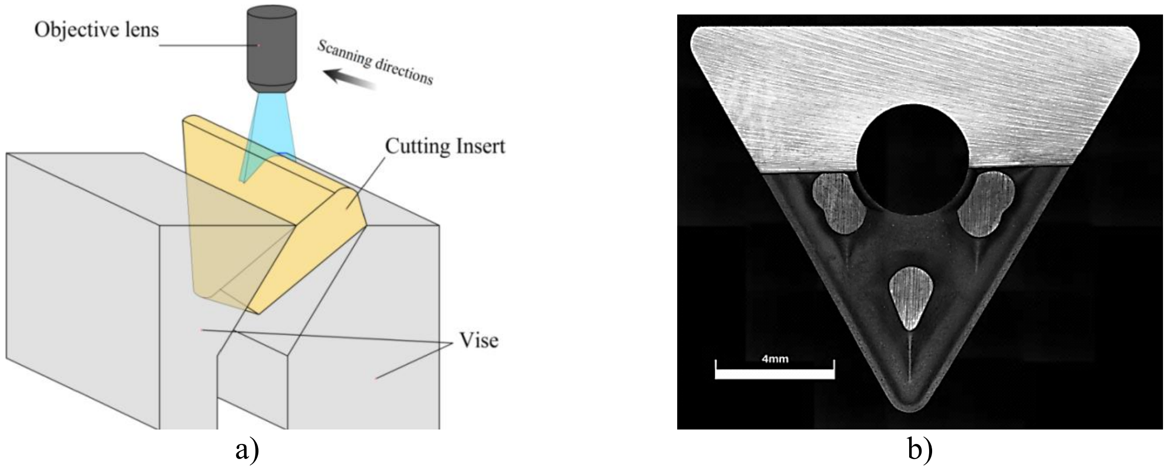

Figure 1. Scanning of the grinded cutting edge of a changeable carbide insert for the skiving cutter performed with the help of 3D laser confocal microscope Olympus LEXT OLS 4100 (a) and optical image of an insert (b)

3. The main results

Figure 2 shows pictures illustrating the condition of the cutting edge of changeable carbide inserts grinded with different diamond wheels. Figures in the pictures show numbers of the wheels used: wheel 1 – grinding powder AC4 with grain size 100/80, wheel 2 – grinding powder AC6 with grain size 80/63, wheel 3 – grinding powder ACH with grain size 40/28.

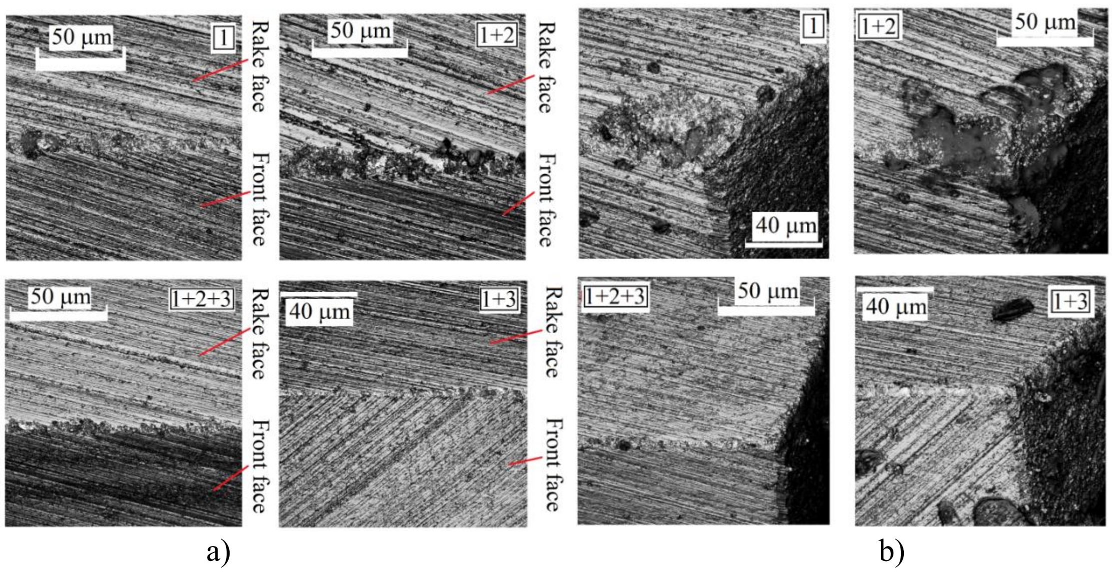

Figure 2. Cutting edge of changeable carbide inserts in the center (a), net to the tip (b) after grinding with diamond wheels: 1 – AC4 100/80, 2 –AC6 80/63, 3 –ACH 40/28

Figure 3 shows 3D profiles of the front surface of changeable carbide inserts after grinding with diamond wheels obtained by laser confocal microscope.

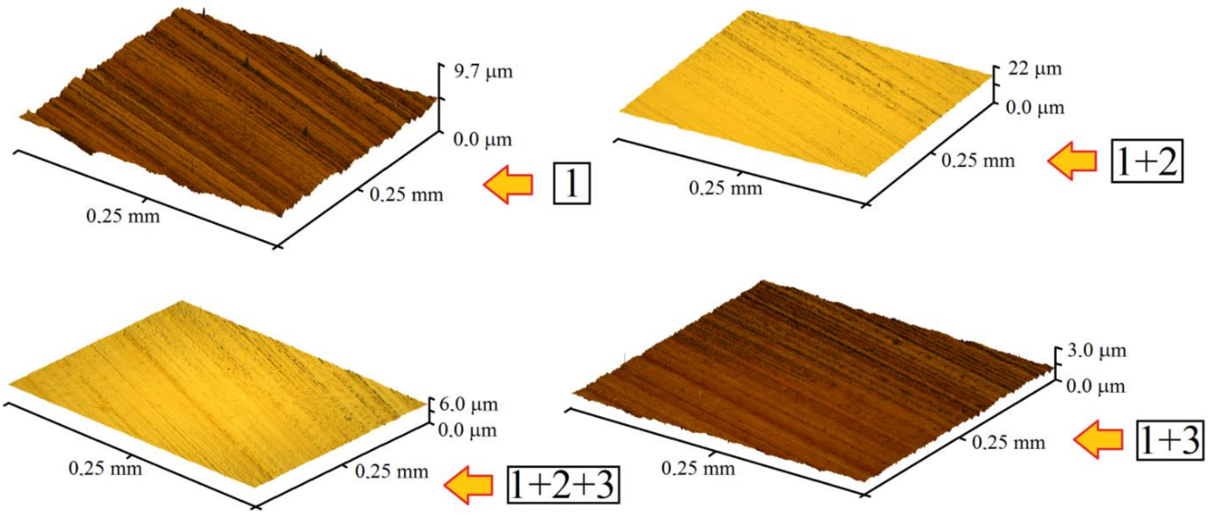

Fig. 3 Profile of the front surface of carbide inserts after ginding with diamond wheels:
1 – AC4 100/80, 2 –AC6 80/63, 3 –ACH 40/28

Figure 4 shows roughness graphs for the front surface of changeable carbide inserts for skiving cutters.

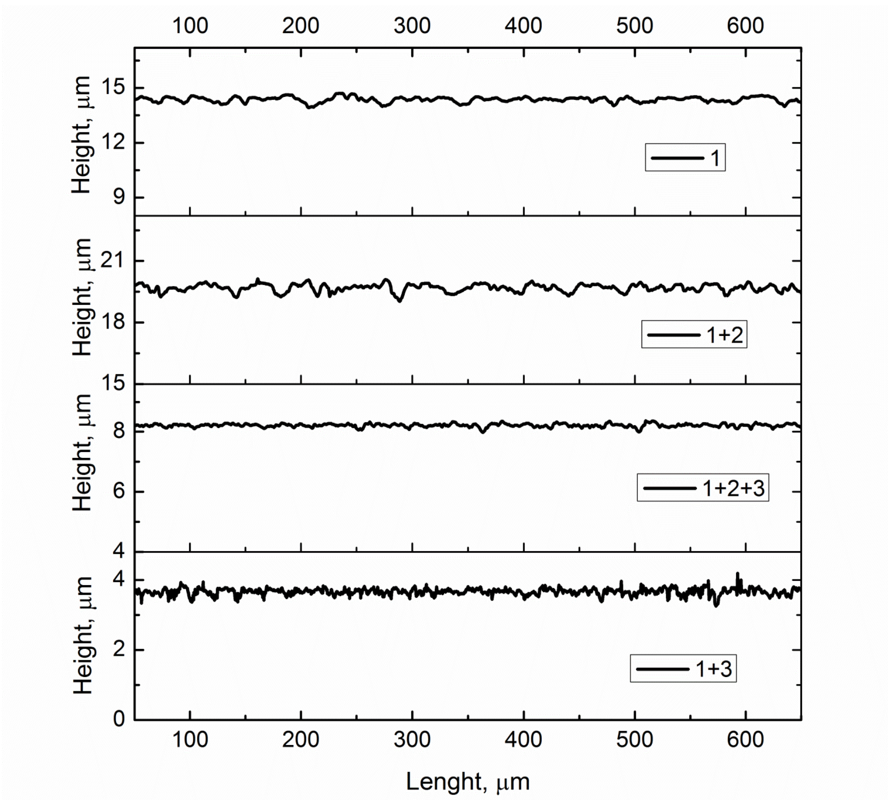

Figure 4. Roughness of the front surface of changeable carbide inserts after grinding with diamond wheels: 1 – AC4 100/80, 2 – AC6 80/63, 3 – ACH 40/28

Table 2 shows roughness values in longitudinal and cross directions (against grinding direction), obtained through an analysis of front surface topograms after grinding with diamond wheels 1, 2, 3 in different consequences.

Table 2. Roughness of changeable cutting inserts edge after grinding with diamond wheels

Diamond wheels	Longitudinal diretion		Cross direction	
	Ra, mkm	Rz, mkm	Ra, mkm	Rz, mkm
Wheel 1: AC4 100/80	0.13	0.9	0.17	1.2
Wheel 2: AC4 100/80 Wheel 2: AC6-80/63	0.14	1.1	0.18	1.3
Wheel 1: AC4 100/80 Wheel 2: AC6-80/63 Wheel 3: ACH-40/28	0.06	0.65	0.06	0.7
Wheel 1: AC4 100/80 Wheel 3: ACH-40/28	0.075	0.77	0.085	0.87

Figure 5 shows cross section profiles of changeable carbide inserts cutting edge after grinding with different diamond wheels obtained by laser confocal microscope.

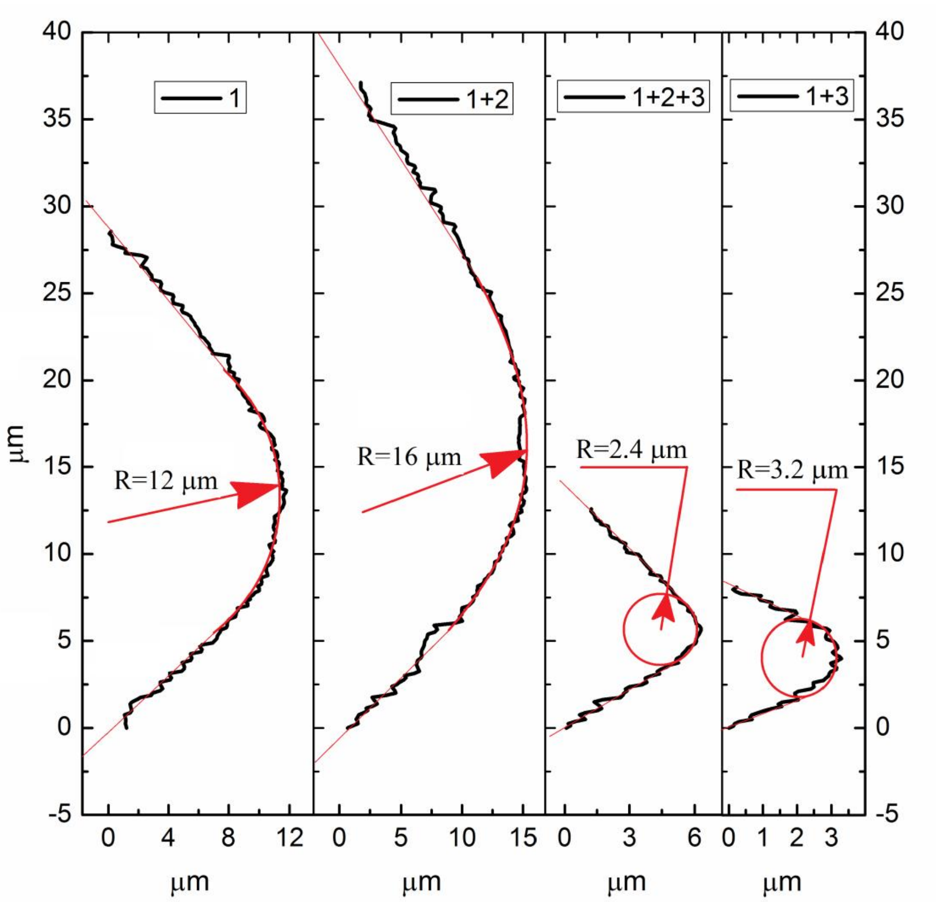

Figure 5. Front section of changeable carbide insert cutting edge after grinding with diamond wheels: 1 – AC4 100/80, 2 –AC6 80/63, 3 –ACH 40/28

4. Discussion

After grinding the front and rear surface of a skiving changeable carbide insert with wheel 1 for rough grinding (grinding powder AC4 with grain size 100/80) the cutting edge of the insert has chippings and the tip of the insert has a large chipping (over 40mkm in length and width). The cutting edge and the tip of the insert after successive grinding with wheels 1 and 2 (wheel 1 – grinding powder AC4 with grain size 100/80, wheel 2 – grinding powder AC6 with grain size 80/63) still has strongly marked large chippings. Extra grinding with wheel 3 (grinding powder ACH with grain size 40/28) after grinding with wheels 1 and 2 leads to considerable reduction of chipping on the cutting edge and on the tip of changeable carbide inserts. 3-D pictures of changeable carbide inserts prove that grinding with wheels 1, 2 and 3 successively provides the best quality of the product.

In case of successive grinding with wheels 1 and 2 the quality of the cutting edge and the tip is equitable with that obtained by successive grinding with the three wheels. Besides a good quality of the cutting edge, such combination allows reducing operational time due to skipping finishing grinding with wheel 2. However, some surface defects are found on the front and the rear surfaces of the changeable carbide insert (see Figure 2b marked as 1+3).

Together with providing a good quality of the cutting edge it is important to provide good quality of the front surface for skiving grinding. The front surface of the changeable carbide insert after grinding with wheel 1 has the greatest roughness. Roughness crosswise to grinding is 30% higher than that longwise. Successive grinding with wheels 1 and 2 did not lead to a better quality of the front surface. Surface roughness grew by 10% as compared to grinding with wheel 1. Successive grinding with wheels 1, 2 and 3 provides the best quality of the insert surface: traces of abrasive treatment are less seen, roughness is the lowest (more than twice less than that after grinding with wheel 1 and combination of wheels 1 and 2). Successive grinding with wheels 1 and 3 (without wheel 2) also gives good quality of changeable carbide insert surface. Surface roughness is only by 25% higher than that after grinding with combination of wheels 1, 2, 3 and by 50% less than that after grinding with wheel 1 or combination 1 and 2.

As it was mentioned above the radius of cutting edge tip round-off is one of important factors effecting deformation conditions and chip making in skiving grinding. In grinding with wheel 1 the radius of cutting edge tip round-off equaled R=12mkm. Fig.5 shows a typical profile of the cross section. Successive grinding with wheels 1 and 2 increased the round-off radius of changeable carbide insert cutting edge up to R=16mkm which is by 25% higher than after grinding with wheel 1 only. The smallest round-off radius R=2.4mkm (which is five times less than after grinding with wheel 1) was obtained as a result of successive grinding with wheels 1, 2, 3. Successive grinding with wheels 1 and 3 (without wheel 2) gave an average radius of cutting edge round-off equaling R=3.2mkm which is 25% more than after successive grinding with wheels 1, 2, 3, but 3.8 times less than that after grinding with wheel 1.

5. Conclusion

The results described above prove:

1. The best quality of grinding of the front and the rear surface of changeable carbide inserts for skiving cutters is achieved by applying successive grinding with wheels 1, 2 and 3 in which grain sizes decrease gradually.
2. Grinding with wheel 1 having maximum grain size (100/80) and grinding with wheels 1(grain size 100/80) and wheel 2 (grain size 80/63) successively gives comparably low quality of surfaces.
3. The best quality of surfaces was achieved by combination of wheels for rough and smoothing grinding (wheels 1 and 3). This combination provides surface roughness

Ra=0.075..0.085mkm and cutting edge round off radius R=3.2mkm which is only by 25% worse than that after grinding with wheels 1, 2 and 3. Besides this combination allows reducing grinding time due to eliminating wheel 2 from the grinding process.

4. Grinding of changeable carbide inserts without using lubricating cooling fluid allows obtaining high quality of working surfaces and cutting edges of skiving cutters.

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