UNIVERSITY OF PITESTI
FACULTY OF MECHANICS AND TECHNOLOGY
SCIENTIFIC BULLETIN
AUTOMOTIVE series, year XVI, no.20 (1)

THE INFLUENCE OF CERTAIN MECHANICAL PROPERTIES ON THE QUALITY OF THE CUT AREA AT THE PLUNGE GRINDING OF CERTAIN CERAMICS

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Abstract: *The technical and industrial development led to the appearence of new materials, with higher properties, which can replace in certain maps, the conventional materials. Among these new materials, technical ceramics also belong to. Ceramics are generally hard processing materials by conventional processes. Physical and mechanical properties of these ones influence the processing conditions and its results understood (productivity, the surface quality, costs etc.). This work proposes to emphasize the influence that some of these properties (e.g. tenacity) exercises on the grinding processed surface quality*

Keywords: ceramics materials, roughness, grinding process, yttria doped zirconia, alumina, diamond tool

INTRODUCTION

Grinding is the most frequently used chip removing process in processing after the integration of ceramics. Grinding offers the possibility of obtaining on the one hand, high cutting efficiency, on the other hand, high class surfaces. The machining (cutting) of ceramics is accompanied by a process completely different from those specific to metals' cutting. A question of peculiar interest of the ceramics cutting is the instability of geometric and technological cutting parameters, which conduct to the apparition of some faults (cracks, breaks, crushings) of ceramics, especially in the area of the edges or of the passages from one cross section to another, which may lead to the alteration of the worked piece's quality.

The quality of the grinding ceramics surfaces is accompanied on the one hand, by the parameters of the grinding conditions and by the constructive characteristics of the diamond tool used in conditioning (processing) but also by the material properties they are made-up of. One of these mechanical properties, having an important role in the development of the grinding process, is the tenacity of ceramics

MEANS AND METHODOLOGY OF EXPERIENCING

To emphasize the influence of tenacity on the machined surface quality (estimated through roughness), there were worked out samples of zirconium ceramics (ZrO_2) partially stabilized with 5 moli% of yttrium (Y_2O_3) and samples of alumina (Al_2O_3). The samples were obtained by a biaxial pressing to a pressure of 400 MPa under the form of some cuboid tips. These are afterwards sintered to a temperature of 1600°C during 5 hours. Both the temperature rise of and fall of were performed very slow (25 °C/h) in order to avoid the appearance of some internal stresses due to thermal beats. On the samples were performed tests connected to some physical and mechanical properties which are presented in table no.1.

Table 1. Physical and mechanical properties of the two materrials used

Characteristic	Al_2O_3	ZrO_2
Density ρ, [g/cm^3]	3.9 - 3.99	5.5 - 5.8
Coefficient of elasticity E [GPa]	360 - 410	180 - 200
Breaking bending strength R_i [MPa], la T=20 °C	390-400	620-630
Critical factor of the tension's intensity K_{Ic}, in [MPa m$^{1/2}$]	4.2 - 5.9	8 - 15
Hardness	1250 HV	1238 HV

In the grinding process were used diamond disks of the type 1A1 175-10-3 (according to STAS 12034-81 or standardization FEPA). For the performance of the grinding disks were used artificial diamonds with different grain sizes (D64, D107 and D181), medium brittle type (DSD-M), uncovered diamonds. The diamonds' concentration used was C75. The diamonds were integrated into a metallic bond (the metallic bond is the one indicated by literature for the grinding of oxide ceramics) of the type Bz 335.
The processings were performed according to an experimental programme built in basis of a complete component plan, where the arguments were presented in table 2.

Table 2 Natural levels appropriate to arguments

Class of processing	The tool used	Cross feed [mm / stroke]	The dependent variable studied	X_1- cutting speed v_d [m/s]			X_2 - feed rate of the mass v_p [m/min]			X_3- cutting depth t [mm]		
				min (-1)	med (0)	max (+1)	min (-1)	med (0)	max (+1)	min (-1)	med (0)	max (+1)
Material ZrO_2 + 5moli%Y_2O_3												
Roughing	D181	6	R_a, R_z, R_y	16	24.7	32	4.5	8.5	13	0.04	0.06	0.09
Semifinis.	D107	4	R_a, R_z, R_y	16	24.7	32	4.5	8.5	13	0.03	0.05	0.08
Finishing	D64	2	R_a, R_z, R_y	16	24.7	32	3.5	4.5	8.5	0.02	0.035	0.06
Material Al_2O_3												
Roughing	D181	6	R_a, R_z, R_y	16	24.7	32	4.5	8.5	13	0.05	0.07	0.10
Semifinis.	D107	4	R_a, R_z, R_y	16	24.7	32	4.5	8.5	13	0.03	0.05	0.08
Finishing	D64	2	R_a, R_z, R_y	16	24.7	32	3.5	4.5	8.5	0.02	0.035	0.06

RESULTS AND INTERPRETATIONS

From a geometrical point of view, roughness is formed as a result of copying the traces left by the abrasive grain on the machined surface and as a result of contingent faults of the ceramics generated during the semiproduction process (especially porosity). Function of the parameters of the processing conditions, an abrasive grain rises microchips of different dimensions, so that, for each processing conditions, will result different qualities of the surface. To illustrate the global influence of the cutting conditions on the roughness parameters R_a and R_z, it was analyzed the influence exercised by the chip's dimension, indicated by the parameter, the equivalent thickness of the chip h_{eq}, calculated with the help of the formula:

$$h_{eq} = \frac{1}{60} \cdot \frac{v_p \cdot t}{v_d} \qquad \text{[mm]} \qquad (1)$$

(the formula is valid for the use of the cutting conditions parameters expressed in: v_p in [m/min], t in [mm] and v_d in [m/s]).
The dependences of medium values of the parameter R_a obtained in the processing of the two materials, function of the equivalent thickness of the chip, are presented in figure no.1.

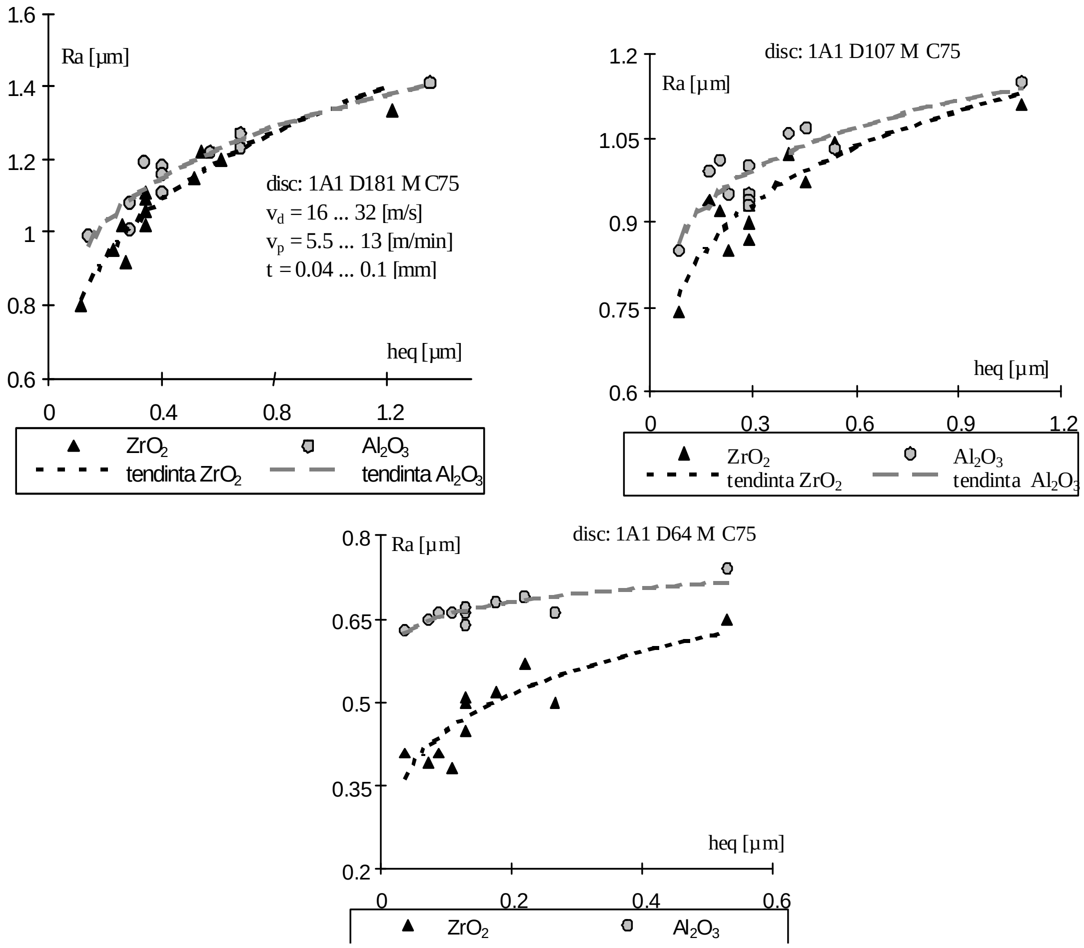


Fig. 1. Dependence of the roughness parameters R_a andR_z of thegrinding processed surfaces

In the case of these three types of processings it can be observed the increasing tendecy of the surface's roughness, with the size of the sampled chips, with only one exception that is the alumina finishing processing. In this case it can be observed a certain limit of the roughness' values, probably due to the porosity existing in sinters.

Considering as an argument the equivalent thickness of the chip h_{eq}, the global parameter of the grinding conditions, there were effectuated calculations for the determination of the dependence relation between R_a and this parameter. This way, one has tried to determine some relations of the form:

$$R_a = C_R \cdot h_{eq}^{\alpha} \qquad (2)$$

where C_R represents a constant which expresses the influence of the processed material, the influence of the abrasive blade used etc. The values of the constants C_R and α are presented in table no.3.

Table 3

ZrO_2 - Y_2O_3		Al_2O_3	
roughing (D181)	$R_a = 1{,}336 \cdot h_{eq}^{0{,}226}$	roughing (D181)	$R_a = 1{,}332 \cdot h_{eq}^{0{,}165}$
semifinishing (D107)	$R_a = 1{,}115 \cdot h_{eq}^{0{,}149}$	semifinishing (D107)	$R_a = 1{,}128 \cdot h_{eq}^{0{,}107}$
finishing (D64)	$R_a = 0{,}71 \cdot h_{eq}^{0{,}199}$	finishing (D64)	$R_a = 0{,}139 \cdot h_{eq}^{0{,}051}$

Moreover it can be observed that as the equivalent thickness of the chips increases the difference between the roughnesses obtained in the processing of the two materials decreases. This way, for rough cuttings (roughing) and for the semifinishing ones, it can be observed that the values of the

roughnesses are almost equals for values of the equivalent thickness of the chip $h_{eq} > 0.5…0.6$ [µm] and different for values of the equivalent thickness of the chip $h_{eq} < 0.5…0.6$ [µm]. This ordering can be explained by the existence of two different microchipping mechanisms corresponding to these two materials.
This thing was observed and explained in basis of the measurement of the specific energy inputed during the chipping process (figure no.2) and in basis of the micrographies realised on the processed surfaces (figure no.3).

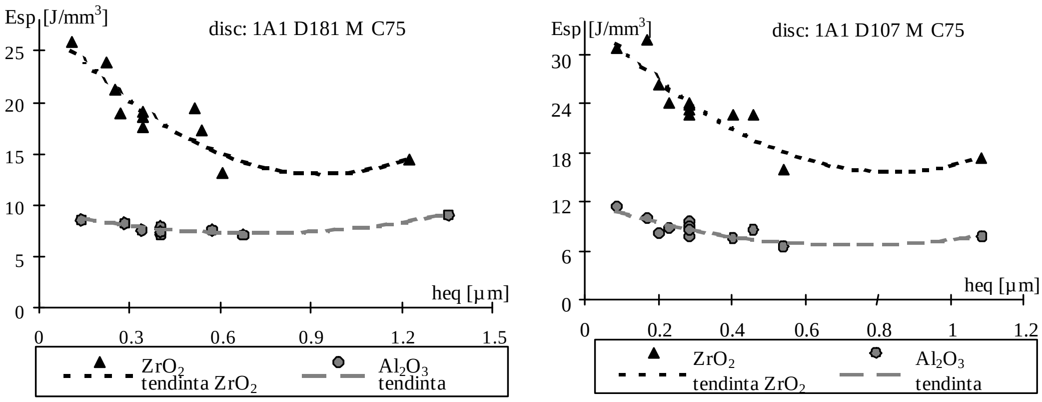
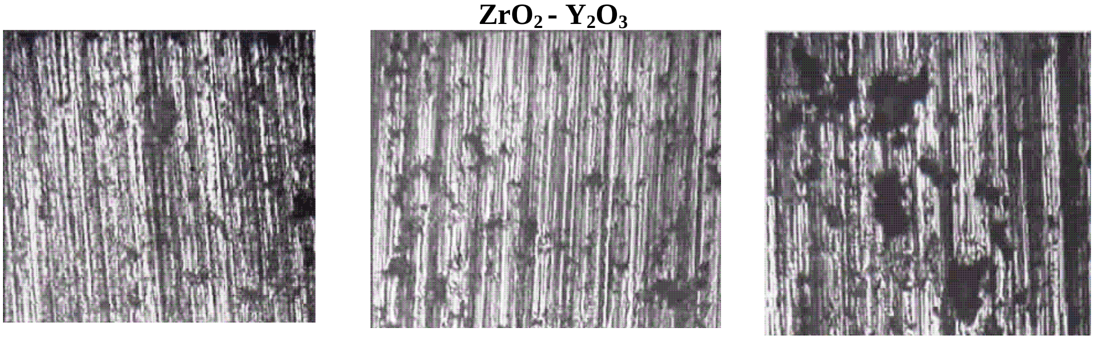


Fig. 2. Specific energy Esp function of h_{eq} in the processing of ZrO_2 and of Al_2O_3

From the above graphics and micrographics analysis result the following conclusions:
In the case of zirconium, the grinding surfaces, have different aspects function of the size of the sampled chip. When the grinding takes place with cutting conditions which determine smaller values of the chip's sizes ($h_{eq} < 0.5…0.6$ [µm]), the chipped surface has an uniform aspect, without too big surface defects. Also taking into account the fact that the values of specific energies E_{sp}, obtained in the processing with these conditions are high, but also the fact that zirconium is characterized by a much bigger tenacity than alumina, makes us affirm that under these circumstances we have to deal with a leading ductile cutting condition realized by the classical shearing process, which will lead to the obtaining of a surface with a better roughness and without too many other surface defects or in the surface layer. As the chipping conditions increase ($h_{eq} > 0.5…0.6$ [µm]), the appeared mechanical stresses lead to the override of the critical factor of intensity of the tension K_{IC}, which will lead to the passage from the leading ductile conditions of chipping to the leading fragile conditions, characterized by breakings and avulsions of ceramics. In fact this passage from the leading ductile conditions to the leading fragile conditions expains the values' decrease of specific energy E_{sp}, because, as it is known, the values of specific energies corresponding to ductile conditions are higher than the values of specific energies of the fragile conditions. This fact will lead to a deterioration of the chipped surface and to the increasing of the chipped surface quality and so to the increasing of the roughness' values.

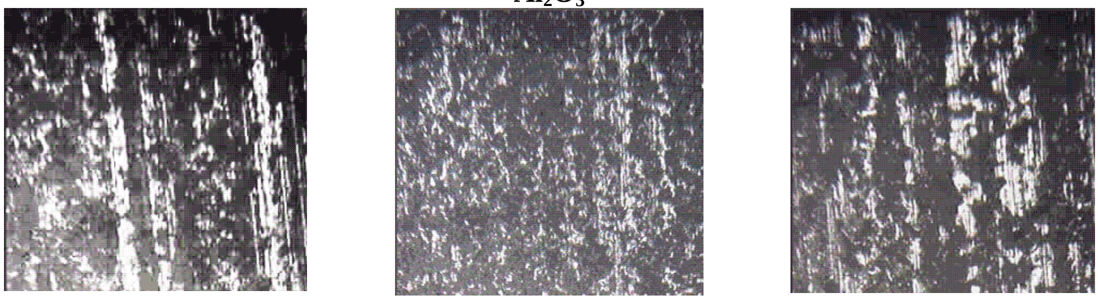
ZrO_2 - Y_2O_3



h_{eq}=0.036 [µm] h_{eq}=0.516 [µm] h_{eq}=0.965 [µm]

Fig. 3. Aspect of the machined surfaces with different equivalent thickness of the chips (ZrO_2 - Y_2O_3)

Al_2O_3



h_{eq}=0.143 [µm] h_{eq}=0.573 [µm] h_{eq}=0.965 [µm]

Fig. 4. Aspect of the machined surfaces with different equivalent thickness of the chips (Al_2O_3)

In the case of alumina processing, it can be observed that whatever the size of the sampled chip, drew by the diamond disk, might be and whatever the diamond disk's grain size (structural composition) might be, the removal (breaking) of the chip is done in fragile (brittleness) condition, condition characterized by multiple crushings and fractures of ceramics. This chipping mechanism is due to the very high fragility of alumina (because of the mechanical stresses which appear during the grinding process, the value of the intensity's critical factor of the stress K_{IC} is exceeded, has as a consequence the apparition of some microcracks), but also to the use of some diamond disks with metallic bond, characterized by a reduced elasticity of the bond, which will lead to the attainment of some surfaces dotted with small cones, characterized by a quite a big roughness. At the same time, it can be noticed that as the chip thickness increases, the depth of these surface defects increases too, which will lead to a deterioration of the machined surface's aspect.

CONCLUSIONS

Lower values of the roughness parameters are obtained while using certain grinding conditions with smaller equivalent thickness of the chips h_{eq}. This thing, determines the using of some grinding conditions with higher external speeds of the abrasive blades v_d and, as well, with values of the longitudinal feed rate v_p and of the smaller cutting depth t;

The characteristics of the manufacturing processes of roughing, semifinishing and finishing differ function of the processed material that is function of the material's tenacity. This way, in the case of alumina working, the roughness parameters R_a and R_z, have higher values towards those obtained in the case of zirconium working, the differences being bigger at values of the grinding condition parameters which determines equivalent thickness of the smaller chips. This fact can be due to different microchipping mechanisms corresponding to the two types of material, especially at smaller values of h_{eq}.

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