**UNIVERSITY OF PITESTI** SCIENTIFIC BULLETIN
FACULTY OF MECHANICS AND TECHNOLOGY AUTOMOTIVE series, year XV, no.19, vol. A

# THE INFLUENCE OF THE WORKING CONDITIONS OVER THE CUTTING FORCES IN THE PROCESSING OF SOME CERAMICS

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***Abstract:*** *Grinding with diamond tools is one of the most used chips removing process in the processing of ceramics. The grinding working is necessary when the requirements of dimensional accuracy and of quality of the surface are not satisfied after the compacting and sintering process. The cutting forces, which are developed during the processing, will exercise a strong influence over the surface quality. Their size is influenced in its turn, by the parameters of the grinding process.*

**Keywords**: ceramics, grinding, diamond tools, cutting force

## INTRODUCTION

Ceramics became lately more and more present in many branches of manufacture, due to their mechanical, chemical and electric properties. In industry there were quickly assimilated wear-resisting, thermic shock resisting, high temperature resisting and aggressive environment resisting ceramics, having a restrained size tolerance.
Besides the problems related to the technology of their building, mechanical processing has an important role. Because of their special properties (high hardness and in the same time high fragility), there may appear special problems in the processing with defined geometry tools (turning, drilling, milling etc.). That is why, clay products that are suitable for chip removing processes are workable with the help of diamond tools (grinding, honing, lapping etc.).
Grinding is one of the most used chip removing process in their processing. Because in the grinding process is involved an undefined number of cutting edges, whose orientation is aleatory, this process differs a lot from the other conventional processes.

## CHARACTERISTICS OF THE PROCESSED MATERIALS AND THE EXPERIMENT METHODOLOGY

The experiments were made on two oxide ceramic materials with different behaviour from the point of view of the chip forming mechanism [5]: zirconium $ZrO_2$ and alum earth $Al_2O_3$.
The test specimens were made of powder compacted by axial pressing at a pressure of 400 MPa in the form of some cuboid tips. These were then sinterised at 1600 °C during 5 hours.
On these samples, there were performed microhardness measurements, using a hardness control device of the type M-400-H1 type. Data related to the size of the impression have been processed with the program Akashi At-201. There was used a load of 500 g, being obtained a microhardness value of 1238 HV for zirconium samples and of 1250 HV for the alum earth samples.
The method used for determining the constituents of the cutting forces in the grinding of the two ceramics was based on measurement of the strains of some elastic masses through an electric parameter. The strains/ deformations measured are due to the two constituents of the cutting force, the conventional component Fn and the crossing angle component Ft. In light of the above, there was built a mounting whose block-diagram is presented in Fig. 1, made of the elastic elements $C_1$ and $C_2$, mounted between two base slabs 2 and 3, the whole assembly being positioned on the engine/ machine compound 4.
The ceramic tip/ plate 1 is solded/ brazed with termoplastic mastic/ cement on the superior tip 2. Under the action of two constituents of the force, the elastic elements $C_1$ and $C_2$ will be compressed and their elastic forming, recorded by the data acquisition system, will be proportional with the values of the forming force constituents.

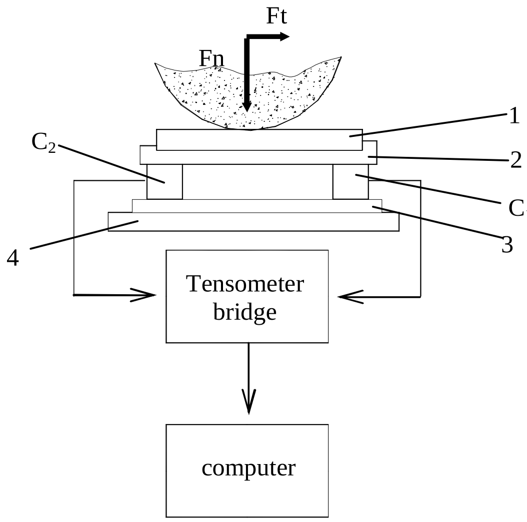



**Fig. 1. Block-diagram of the mounting used for measuring the grinding force constituents**

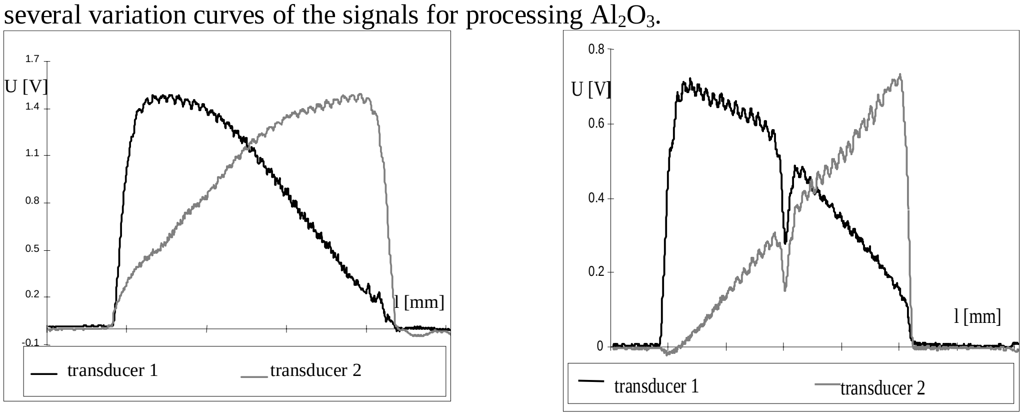
The signals transmitted by the resistive electric transducers have been acquired and recorded on the computer hard-disc and then they have been processed.
The cutting workability were performed using two diamond discs/ plates with metal bond of 1A1 type, with the grain sizes D181 (rough cutting) and D107 (semifinishing), and the parameters of the cutting conditions were alternated/ modified as :
- circumferential speed of the diamond disk $v_d$ = 16-32 [m/s];
- cutting longitudinal feed of the mass $v_p$ = 5.5 – 13 [m/min];
- cutting depth t = 0.03 – 0.1 [mm]

**Experimental results**

From the diagrams obtained, two are important for this study:

- The conventional constituent of the grinding machining force Fn, obtained as an average of the values measured along the ceramic plate in five distinct points;
- The crossing angle component of the grinding machining force Ft, obtained as an average of the values measured along the ceramic plate in five distinct points;

In order to emphasize the curves variation of the signals recorded during processing, Fig. 2.a) presents several variation curves of the signals given by the transducers for processing $ZrO_2$, and Fig. 2.b) several variation curves of the signals for processing $Al_2O_3$.




a) b)

**Fig. 2. Variation of the signal given by the resistive transducers during processing a) $ZrO_2$; b) $Al_2O_3$**

As it can be noticed from the analysis of the Fig. 2.a), in the case of processing $ZrO_2$ the two transducers work almost symmetrical, as the ceramic plate used for determinations, with the sizes 80 ×

80 × 10 [mm], has been symmetrically placed to the axes of the two transducers. In the case of processing $Al_2O_3$, it can be noticed halfway the processing distance, a loss of the signal given by the two transducers. This is due to the fact that for performing the experiments, there were used two alum earth tips with the sizes of 55 × 55 × 10 [mm], brazed on the counter punch with a distance between them of about 2 [mm], and these "losses" of signal is during the time when the diamond abrasive blade follows this distance without cutting.

Another aspect that should be noticed is the wavy aspect of the signal. This variation may have at least three explanations:

- the appearance of vibrations during processing due to the stiffness/ rigidity decrease of the technological system, introducing into it the dynamometric mass functional to accomplish the experiments. Their amplitude increases as the force recorded by either one or the other transducers increases;
- the bug defects of the diamond disk, which may have waves. In this case, the diamond grains from the active layer of the disk, will "raise" chips of different thickness (a grain which will be in the area of a depression of the wave will raise a chip of smaller sizes, and one on the beak of a wave will raise a chip of bigger sizes), so there will be a variation of the abrasion forces from one grain to another;
- if the volume of the chip raised by a certain grain passed the volume of the pore in which the chip is placed, then the respective grain can no longer cut/ chip away, so that, the resulted force will deform the elastic technological system. Due to this forming, takes place a discharge/ unloading of the grain that will cut, so there will take place a discharge of the elastic technological system.

Whereas between the constituents Fn and Ft is a certain dependence relation, next there will be presented the analysis related to the conventional constituent of the cutting force Fn.

One of the most important parameters function of which one can give a realistic interpretation for the grinding processes is the equivalent thickness of the chip $h_{eq}$ [μm]. Its importance is given by the fact that it brings in its calculation formula (1) the whole three parameters of the working process that were alternated during experiments, so one can give a global interpretation of the process [5].

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

(the formula is available for the use of the cutting conditions parameters expressed in : $v_p$ in [m/min], t in [mm] and $v_d$ in [m/s]).

So, as it can be noticed from Fig. 3, both in the case of $ZrO_2$ processing, and in the case of $Al_2O_3$ processing, the constituents of the cutting force record some risings as the $h_{eq}$ increases, both in the case of rough cutting and in the case of semifinishing grinding.

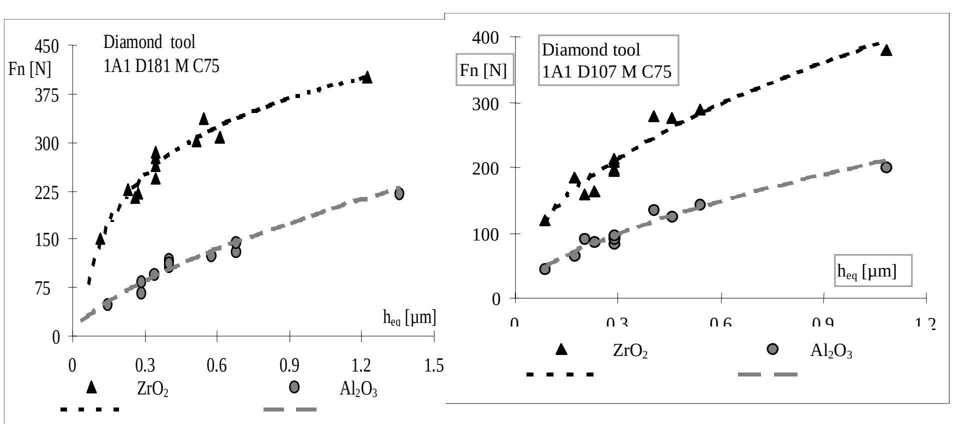



**Fig. 3 The variation of the conventional constituent of the cutting force function of the $h_{eq}$**

As the influence of the grinding conditions' parameters ($v_d$, $v_p$ and t) is concerned, on the conventional constituent of the cutting force, analysis performed using the diagrams from Fig. 4 for zirconium and Fig. 5 for alum earth, it can be noticed that:

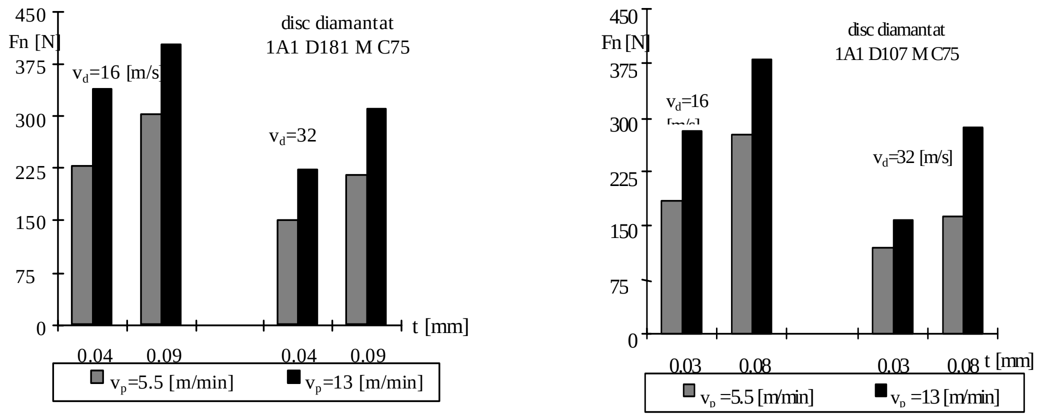



**Fig. 4. Dependency of the conventional constituent values of the cutting force to the grinding conditions ($v_d$, $v_p$ and t), for $ZrO_2$ processing**

- The increasing of the values of the longitudinal cutting feed of the mass $v_p$ and of the cutting depth t leads to an increasing of the cutting force constituents' values both for zirconium and for the alum earth. This phenomena is due especially to the fact that these two parameters influence directly the thickness of the chips drawn by the cutting edges of the grinding wheel grains, which will lead to the increasing of mechanical stresses. In addition, by increasing the values of these two parameters, it also increases the amount of chips raised by each grain. In this situation, these chips will not get into the pore in front of each grain, that will lead to a "loading" of the diamond abrasive blade, so to an increasing of the cutting force constituents' values.

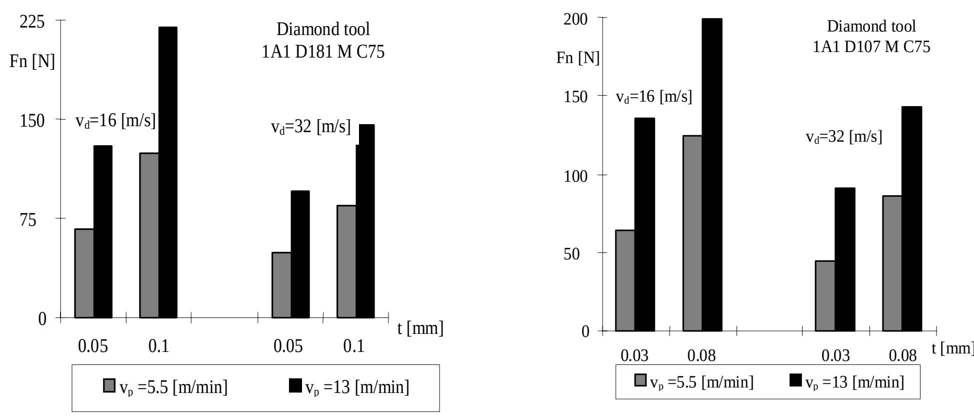



**Fig. 5. Dependency of the conventional constituent values of the cutting force to the grinding conditions parameters ($v_d$, $v_p$ and t), for $Al_2O_3$ processing**

- The increasing of the circumferential speed value of the diamond disk $v_d$ leads to the drop of the cutting force constituents. This thing is due to the fact that an increasing of the value $v_d$ leads to a decrease of the equivalent thickness of the chip $h_{eq}$ that is to a diminution of the size of the chip that must be draw by the disk. In the same time increasing the value of the size $v_d$, the same volume of chips will be raised by a bigger number of abrasive grains, to each grain tempering a smaller volume of chips. In this situation, when each grain raises a smaller volume of chips, the forces that act on each grain will be smaller.

## CONCLUSIONS

For the subordinated variables "components of the cutting force Fn and Ft" studied one can draw the following conclusions:

- The components of the cutting force record raises as the $h_{eq}$ increases, both for the coarse grind and for the semifinishing grinding.
- From the graphical analysis, the independent variable taken into consideration have a different influence:

  - the variable $v_d$ influences significantly the components of the cutting force the increase of the crossed speed of the diamond disk $v_d$ (from 16 to 32 [m/s]), produces a decrease of the values of the cutting force constituents (of about 30-34%);
  - the variable $v_p$ also influences significantly the components of the cutting force the increase of $v_p$ (from 5.5 to 13 [m/min]), produces an increase of the values of the cutting force constituents (of about 45-90%);
  - the variable t is also significantly influenced by the components of the cutting force the increase of t (from 0.04 to 0.09 [mm] for $ZrO_2$ and from 0.05 to 0.1 [mm] for $Al_2O_3$), produces an increase of the values of the cutting force constituents (of about 35-75%).

- As about the nature of the processed material, it was noticed that the values of the subordinated sizes have the order $Y_{ZrO_2} > Y_{Al_2O_3}$ they have the same ordering relation as the mechanical properties and especially with the toughness / tenacity of the studied materials.
- The influence of the diamond disks grain size: if we take into account the size of the chip removed (by the parameter "sum of the cross sections of the chips" simultaneously removed from the machining allowance by the cutting edges of the abrasive blade grains, calculated as the multiplication of the equivalent thickness of the chip $h_{eq}$ and the size of the cross feed $s_{tr}$), it can be noticed that the cutting forces generated during the grinding wheel D107 processing are bigger than those generated by the D181 grinding wheel processing. This variation is due mainly to the different number of grains from the content of each disk and because of the different cutting capacity and the remove of chips from the cutting area of the two disks.

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