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A PARAMETERS' SYNTHESIS OF GRINDING PROCESS MODELING FOR CARBIDE DRILLS DEEP HOLES AND SMALL DIAMETER

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Abstract— Grinding process is increasingly used in surface finishing of materials that are hard to process using other methods, such as hard alloys of nickel, titanium, hardened steels, ceramics, carbides. The performance of grinding process is conditioned by a number of factors related to the characteristics of the work-piece, grinding wheel and its properties, cutting mode, cutting forces, heat output, etc. This paper aims to make a model of the grinding process of carbide drills for deep holes of small diameter. Carbides raise a number of problems in grinding. This has been the subject of many research studies. In addition, the carbide drill for deep holes of small diameter requires increased dimensional accuracy, a surface with low roughness, and no physical or chemical altered surfaces during processing. The model developed contains the necessary elements of an efficient grinding process for this type of drills.

Keywords — carbide, drills for deep holes and small diameters, grinding, modeling.

I. INTRODUCTION

CUTTING processing plays an important role in modern manufacturing. As one of the most important manufacturing processes, grinding represents about 20-25% of total cost on processing operations [1], and even more to modern tools made entirely of metal carbides. This is traditionally regarded as a final machining in the production process of the component surfaces which require close tolerances and small surface roughness [2].

Grinding is conditioned by a number of factors that affect its performance: work-piece, the structure of the grinding wheel and cutting regime parameters, the cutting medium, vibration, forces, heat generated.

Most research refers to the elements involved in the development process rather than the surface to be machined and the interaction between the grinding wheel and the surface.

The performance of the process, in general, corresponds to the factors that affect either the cost or quality, while the input parameters are usually represented by the work-piece, the grinding wheel, machining parameters, the cutting medium, as well as the control methods of the machine tools. It can be said that all performance characteristics depend on the input parameters in the process of removing material from the surface and the contact between the surface to be machined and the grinding wheel.

II. ACTUAL STATE OF RESEARCH CONDUCTED ON GRINDING PROCESS

Grinding by its complexity has raised many problems over time, and their resolution was the subject of research in the field. Research on the elements involved in both the process and the factors influencing it was carried.

The grinding wheel has been subject of research regarding structure and shape, topography, in order to reduce wear and increase its sustainability processing high hardness materials such as carbides.

From the point of view of the abrasive properties, research has focused on the nature of the material grains and binder. Electrocorundum and silicon carbide grains of abrasive wheels were analyzed and the research showed a number of problems that occur in grinding process: combining with the processed materials, low thermal conductivity and high chemical activity in contact point. Abrasive grains of the transition metal compounds (borides, carbides, nitrides) were proven to be able to remove all or part of these problems [3].

Research has shown that not all abrasive grains participate in chip removal. Regarding on, research has been focused in the development of a methodology for determining an experimental method of calculation the number of active abrasive grains [4].

Studies on the action of abrasive grains on the grinding surface have shown that they are concentrated on the front surface of the grinding wheel. It was found that with decreasing grain size, the number of grains is increasing in a binder, and surface finish roughness is less [5].

Binder hardness, the forces connecting the diamond grinding grains and binder materials, and porosity are relevant in determining the grinding capacity of the wheel [6]. Porous grinding wheels demonstrated a greater capacity than conventional ones and are more easily balanced and reconditioned [7].

The results of research have helped in the identification of the structure of grinding wheels that satisfy the conditions of optimum processing, from a quality point of view of the surface obtained and from the cost and time needed for processing [8]. Grinding wheel topography is important in the grinding process development. Uniformity of grain cutting performance has a significant impact on the depth of penetration, roughness and superficial layer quality [9].

Grinding process is accompanied by the phenomenon of grinding wheel wear, in various forms, such as grinding wear, plucking grain from the binder and or the wear as a result of chemical reactions [10].

There were some discussions on how the grinding wheel stiffness can be controlled. We have identified factors that influence the rigidity: the thickness of the disc, the modulus of elasticity and diameter [11].

The main objective of most researches was to determine the grinding wheel wear in processing various materials and increasing its lasting period [12].

Grinding processes are based on the interaction between the abrasive grain and the work piece, having as influencing factors the temperature, the pressure at the point of contact and chemical reaction between the grain and the material. The most effective is the cubic boron nitride abrasive grain [13].

The optimization of grinding process was performed by ensuring the uniformity of abrasive action, efficient operation, reducing friction between the grains and the processing surface and between the binder and the surface, as well as reducing the heat released during the process.

Characterizing the work-piece is difficult in the context of processing by grinding. Chemical properties are very important in the interaction with the grinding wheel and cooling [14].

The surface quality depends on the processing method of grinding, the number, size and distribution of the abrasive grains on the useful part of the abrasive disc [15].

The use of water for liquid-based cooling is suitable for conventional abrasive wheels, but not for the super abrasive, which reacts with water at high temperatures [16 -17].

The grinding process was studied and designed in terms of conditions imposed by the material, cutting data, cutting forces [18].

We conducted research on correlating the factors influencing the grinding process with the time and costs related to it [19].

The optimization was meant to minimize the costs. The studies were based on a set of constraints on the accuracy of processing, the roughness of the surface, the depth of cut, the technical characteristics of the cutting tool correlated to the cutting system [20]. Considering the structure of the grinding process, models have been developed, taking into account the important elements in processing efficiency.

Fig.1. contains the model of grinding process, with all the involved elements.

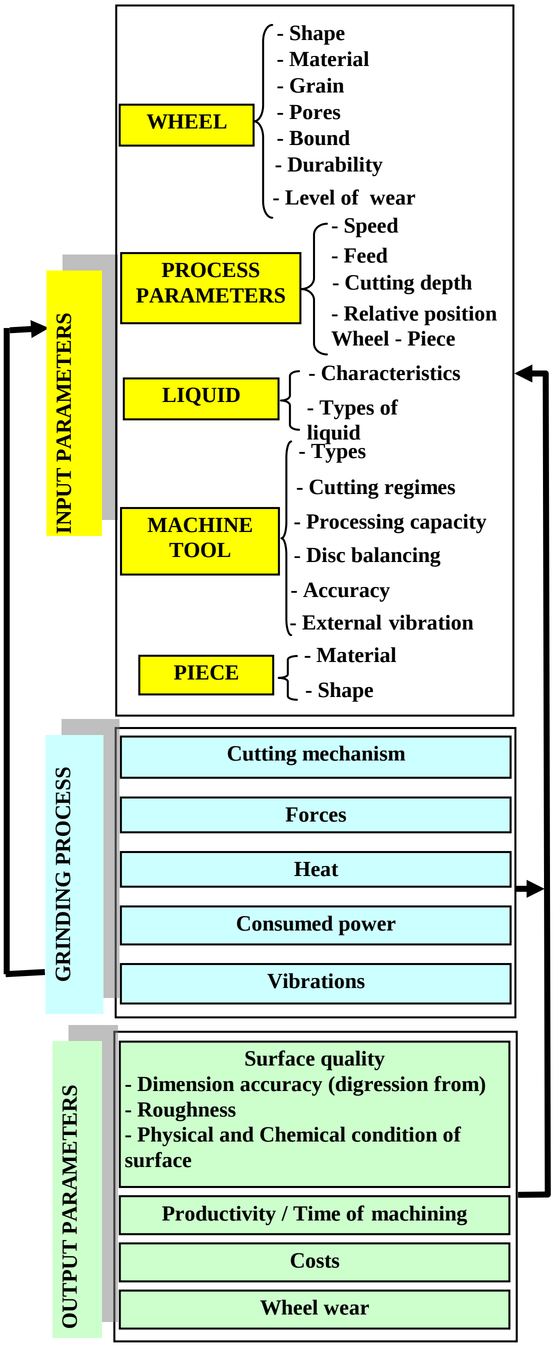


Fig.1. The model of the grinding process

III. PROCESSING DRILLS FOR DEEP HOLES OF SMALL DIAMETER MADE OF METALLIC CARBIDE

Deep holes cannot be processed with regular drills due to the technological difficulties that arise. Drills for deep holes are executed with one or more cutting edges, for continuous or discontinuous cutting and allow external or internal chip evacuation.

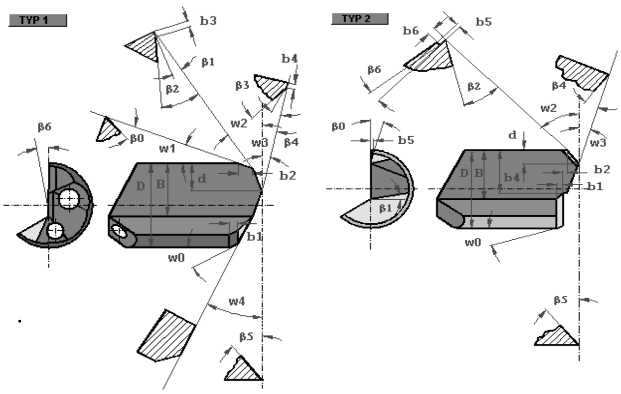


Fig.2. Types of drills for deep holes [21].

These drills are used for small diameters (∅ 0.25 ÷ 20 (mm), hole length L ≤ 25D), given their limited stability during cutting. The processing is carried out intermittently in order to allow discharge of chips and cooling the tool working part.

They can be found in various forms of construction, with helical, wide or straight pits.

To process hard chipping materials, to increase productivity, these drills are made of metallic carbides entirely or just their active part. The processing of drills is done with grinding wheels and we can distinguish several features:
- The metallic carbides that they're made of impose several restrictions.
- The surfaces have complex shapes, small sizes, requiring high dimensional accuracy.

These tools are built in high class accuracy or normal precision with diameters between 0.25 (mm) and 20 (mm), when the upper deviations are 0, and the lower ones are between - 0.022 and - 0.009.
-processed surface roughness (Ra) must be between $0.025 \cdot 10^{-3}$ and $0.4 \cdot 10^{-3}$ (mm).
-the tool must not have burrs
-the tips and the edges should not be affected by heat.

To design an optimal grinding process metal carbides in general and drills for deep holes, in particular, I propose the following performance criteria: the quality of the machined surface, the grinding wheel condition after machining, cutting fluid wear, productivity/processing time and the cost of processing.

These performance criteria, still considered the output parameters of the process, depend on the elements involved in the development of processing that are considered input parameters.

Following the performance criteria proposed, we can identify the correct grinding demands for carbide drills for deep holes and small diameters.

Surface quality:
Dimensional accuracy – Grinding process should ensure greater precision if it is considered that they have small diameters (ranging from 0.25 (mm) to 20 (mm)) in which upper deviations are 0, and the lower ones are negative, between -0.022 and -0.009. Surfaces have complex shapes. Some drills are equipped with cooling channels and other inner channels open outwards for splinter evacuation. The position of the channel is well defined in relation to the geometry of the drill. Beatings are between 0.008 and 0.2 (mm).
Factors influencing dimensional accuracy are:
- *Machine tool* has high precision, its rigidity is important in the accuracy processing. Its construction ensures a vibration-free operation.
- *Grinding wheel* is a key factor in grinding processes. Before processing, grinding wheel is checked in terms of the degree of wear, diamond discs before installing are checked for cracks or detachment from the body, defective discs not being allowed. Grinding requires static and dynamic balancing before processing.
- *Cutting fluid* should have high capacity cooling for both the work piece and the grinding wheel to ensure dimensional accuracy.
Roughness: It is small, roughness (Ra) value is between 0.025 and $0.4 \cdot 10^{-3}$ (mm). It depends on cutting speed, feed, depth, cutting medium and grinding wheel.
- *Cutting speed* depends on the work piece and the grinding wheel used. At low cutting speeds obtained roughness is smaller. Cutting speed is between 20 and 25 (m/s), but can exceed these values, depending on the grinding wheel and machine tool used.
- *The feed* is very important in achieving roughness parameters. Its values are between 0.02 and 0.01 (mm/rotation) for roughing, and between 0.002 and 0.005 (mm/rotation) for finishing.

Theoretically, depth of cutting does not influence the roughness, but it is very important for the physical-chemical status of the surface. Its values vary between 0.02 and 0.1 (mm) for roughing and between 0.02 and 0.0025 (mm) for finishing.
Physical-chemical status of the surface:

It is necessary that the processed surface has no cracks, tension must be appropriate, no burns, not oxidation, there must be no chips that have adhered to the melted surface.
-*The grinding wheel* influences the physical-chemical status of the surface by the abrasive grains' nature, which should not react at high temperatures with the material to be processed. Grinding wheel wear increases at high temperatures at the contact surface and may cause burns or oxidation.
The length of contact surface between the disc and processed surface increases the tension and compression.
-*Cutting speed* influences the appearance of cracks and their propagation. Increasing the speed at the same depth of penetrating, the angle of crack propagation increases. Increasing cutting speed increases the residual stresses. The feed is closely related to cutting speed.
-*Depth of penetration* is a factor that can cause cracks in the processed layer if not chosen properly [20]. It is interdependent with cutting speed. We recommend working with low depth of penetration and low feed and high cutting speeds.

-*Cutting fluid* should have high cooling capacity to lower the temperature in the contact area and do not react with processed surface.

Grinding wheel status: For processing drills with small diameters the shape of wheels is tapered, profiled, pot type. Grinding wheel wear is manifested by plucking grains of the binder, the particles of processed material that adhere to the surface of the wheel and the abrasive wear of the grain's tip.

-*Cutting regime* is important in terms of sustainability of the grinding wheel.

-*Cutting speed* has an influence on the types of wear occurring in the grinding wheel. At low grinding speeds the particles of material adheres to the wheel surface and grinding wear occurs, and at high speeds, wear through oxidation occurs.

-*The cutting medium* is important in maintaining the cutting ability of the grinding wheel. It must ensure proper cooling, so it does not chemically react with the grinding wheel. It plays an important role in eliminating the phenomenon of wear by adhering particles to the grinding wheel surface.

Productivity - the number of pieces processed in a period depends on the cutting regime, the cutting speed, machine tools performance, grinding wheel properties and cutting environment.

The cost of the manufacturing depends on the cost of the grinding wheels, the cost of cutting fluid, the rate of depreciation of the cost of the machine tool, cutting fluid consumption and its recyclability.

Identifying for each output parameter, the input parameters that influence them, it was necessary to prioritize them, made with the "triple cross" method.

The method is based on functional analysis of a product. Identifying its functions, we compare to each other, with the following scale of values: / - equal important, 1 - slightly important, 2 - medium importance, 3 - very important. The weight of each function is calculated using a computer program for share of each function in the value (source: www.btscpi.fr) [22].

By analogy, for each output parameter was determined the relative share importance of each input parameter participating in the development process.

Initial state of the grinding wheel, precision and stiffness of the machine tools are more important for dimensional accuracy. (TABLE I, Fig. 3)

TABLE I
THE WEIGHT FACTORS INFLUENCING DIMENSIONAL ACCURACY

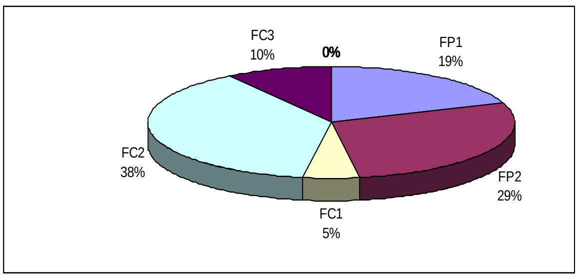


Fig. 3. The relative importance of the input parameters that ensure dimensional accuracy

For all the others output parameters, I determined the relative importance of the input parameters which influence it.

Roughness depends, in principal, on the properties of the grinding wheel, feed rate and cutting speed.

Grinding wheel wear, penetration depth, cutting speed and the size of the surface area of contact between the grinding wheel and the machined surface determine the physical-chemical status of the surface.

The durability of the grinding wheel is conditioned, mainly, by the nature of the grain, granulation, the binder type, cutting speed.

Productivity is relatively correlated to the properties of the grinding wheel, cutting speed and machine tool.

Requirements regarding processing costs are the cost of grinding wheel, the depreciation rate of the machine tools, the cost of the cutting liquid.

Starting from the general requirements of an efficient grinding process, and the specific conditions of grinding carbides and special deep drilling drill bits processing of small diameter, we will enunciate all the requirements, they will prioritize and ultimately select the most significant manufacturing process ensuring optimum efficiency.

Designing an efficient grinding process for deep drilling tools made of carbide metal required initially to identify all those related to design, technological system components for the grinding process and not least those that manufacture, sell, maintain and manage these tools.

Using the documentary research, questionnaires, direct discussions, I identified a number of needs/demands for efficient grinding carbide drills (small diameter).

Finally we will develop a model of optimal grinding process for these tools. (Fig.4)

The factors that influence dimensional accuracy		%
FP1	Stiffness of machine tool	19,0 %
FP2	Precision machine tools	28,6 %
FC1	Vibrations	4,8%
FC2	Status grinding wheel	38,1 %
FC3	Static and dynamic balancing of grinding wheel	9,5%

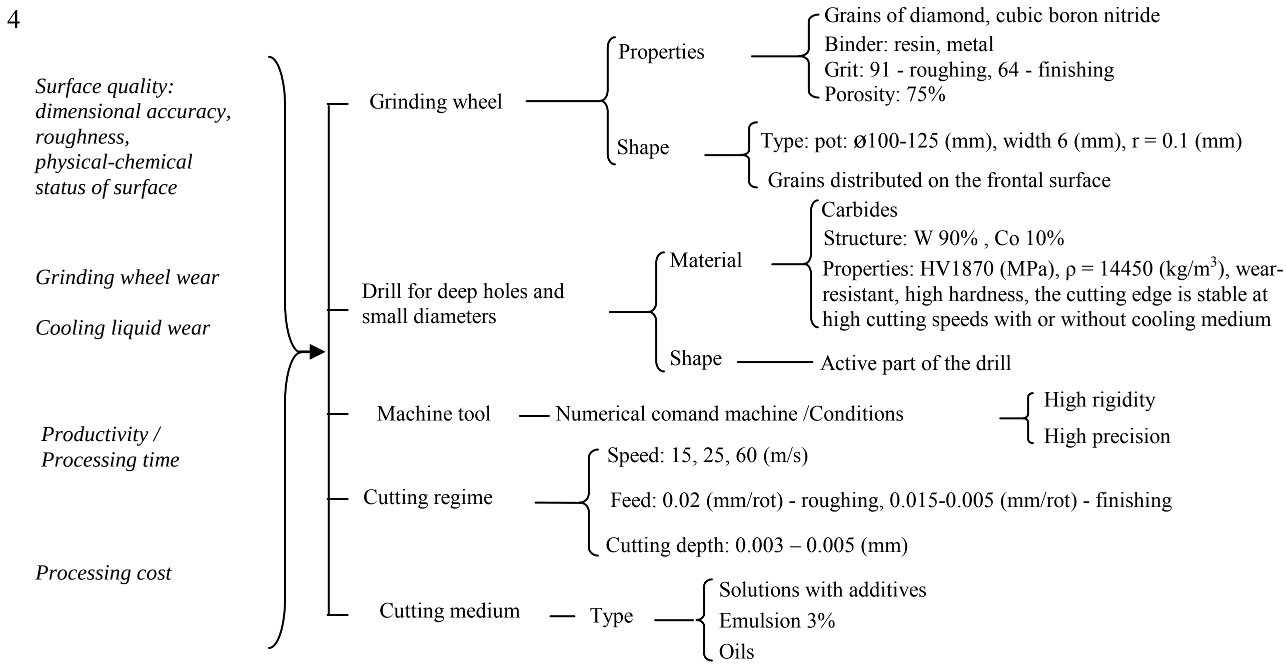


Fig. 4. The influence of input parameters on performance criteria

The researches have identified the following problems: - grinding wheel must be made of diamond abrasive grains or cubic boron nitride, distributed in a mineral binder (resin), the disc must have a high porosity.
- The grinding wheel's surface coefficient of friction and material hardness ratio are dependent on the wheel surface and the work piece characteristics (yield strength, plasticity)
- Surface roughness of the tool depends on grit abrasive particle size, cutting disc's structure and regime.
- Cutting regime has a significant influence on the grinding process
- Critical cutting depth is 3-5 $\cdot 10^{-3}$ (mm), and depends on cutting speed
- Normal and tangential components of the cutting forces are dependent on the cutting speed and depth of penetration.
- The heat generated in the cutting process can cause damage to the finished surface and damage processing system elements;
- Use of proper coolant is important for reducing the amount of heat produced and to avoid thermal defects on edged drill tip
- There are strategies for reducing the amount of liquid used even for dry grinding
- Cutting medium, its composition depends on the nature of the abrasive grain
- A high rigidity of the processing equipment is needed
- For treating small areas, such as the areas of these drills for deep holes of small diameter, it is important that grain distribution to be on the frontal surface of the grinding wheel. Experimental research led to an optimal manufacturing for drill with small diameter, made of carbide (Ø = 1- 6 (mm)).

Input parameters:
Grinding wheel: It is pot type, 100 (mm) diameter, 6 (mm) width, 4 (mm) height, radius 0.1 (mm).
Properties – The wheel has grains of diamond with grit size of $64 \cdot 10^{-3}$ (mm), in mineral binder (resin), with porosity 75%. (Fig. 5)

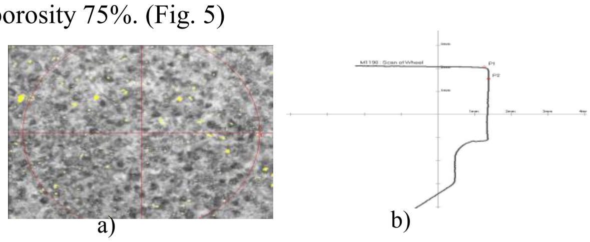

a) b)

Fig. 5. Grinding wheel
a) Grain Distribution in binder b) Grinding wheel profile

Process parameters: cutting speed 15-60 (m/s), feed 0.02 - 0.005 (mm/rot), cutting depth of 0.004 (mm).
Cutting fluid: It is oil based in abundant flow at a pressure of 10^6 (Pa).
Machine tool: CNC machine 5-axis
Regrinding piece (in this case): the drills for deep holes of small diameter (Ø1.75 - Ø 5.5 (mm)) made of tungsten carbide, wear resistant, stable at high speed cutting. The active part of the drill is worn. (Fig. 6)

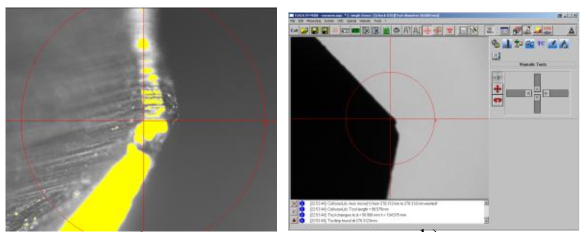
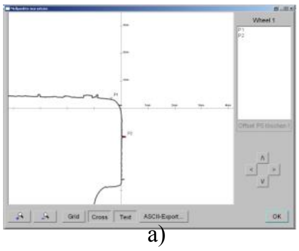

a) b)

Fig. 6. Worn drill: a) Worn edge b) Worn tip

Output parameters:
Dimensional precision: These drills require precision. (Upper deviations are 0 and the lower between (-0.025

and -0.006). Drills processed are within the limits of tolerance.
Roughness: Ra is small, values between $0.025 \cdot 10^{-3}$ mm and $0.1 \cdot 10^{-3}$ mm
Physical-chemical state of the surface: no cracking, is not affected by the heat generated during the grinding process, it shows the machined surface melted chips, no oxidation, burns (normal color).
Grinding wheel status: types of wear that were observed: profile usage, plucking grain abrasives. (Fig. 7)


a)

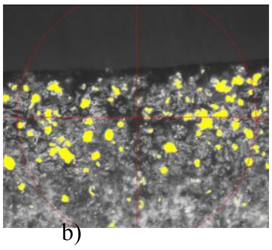

b)

Fig. 7. Grinding wheel wear types:
a) Wheel profile wear b) Plucking grains

Grinding wheel wear appeared after 20 hours of working.

IV. CONCLUSIONS

The study took as a starting point for grinding processing researched on, in general, but especially working with abrades metal carbides. The processing of these materials is more difficult by other processes, machining abrades the most appropriate. In this context, I remember a few necessary requirements of an efficient processing by grinding, mentioned above. We have developed a model of processing by abrades, encompassing elements involved in processing characteristics (input parameters), the factors that influence the development process and the elements resulting from this process (output parameters). We identified the most important performance criteria and analyzed the influence of input parameters on process requirements abrades, with application to drill for deep holes of small diameter carbide. These requirements are verified in practice.

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