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RESEARCH POSSIBILITIES IN CORRELATION BETWEEN THE SURFACE ROUGHNESS AND TECHNOLOGICAL PARAMETERS OF STONE MACHINING

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Abstract:
The stone products with different sizes, geometries and materials - like machine tool's bench, measuring machine's board or sculptures, floor tiles- can be produced automatically while the manufacturing engineer uses objective function similar to metal cutting. This function can be minimising of the manufacturing time or the manufacturing cost, in other cases it can be maximising of the tool's life. To use several functions manufacturing engineers need an overall theoretical background knowledge which can give useful information about the choosing of technological parameters (e.g. feed rate, depth of cut, or cutting speed), the choosing of applicable tools or especially the choosing of the optimum motion path. A similarly important customer's requirement is the appropriate surface roughness of the machined (cut, sawn or milled) stone product. This paper's first part is about five months long literature review, which summarizes in short the studies (researches and results) considered most important by the authors. These works are about the investigation of the surface roughness of stone products in stone machining. In the second part of this paper the authors try to determine researching possibilities and trends which can help to specifying the relation between the surface roughness and technological parameters. Most of the suggestions of this paper are about stone milling, which is the least investigated machining method in the world.

1. Introduction

We can usually see the different stones and stone products as decorating elements or casing materials but they are also important in the mechanical engineering practice. Thanks for their density, temperature tolerance, wet resistance, abrasion resistance and dimensional stability they are suitable for machine tool's or measuring machine's elements (e.g. benches or boards). There is not as a wide literature on stone machining as on metal machining despite of stone machining being as important as metal's and it has a same long past. However the applied technologies can be parallel, the machined stone materials are heterogeneous thus before and during stone machining the investigation (of the material's properties) is necessary. In this way the manufacturing can be more predictable and safer as well. Nowadays the preparation of the appropriate background knowledge is an important task of the world's researchers. The authors in this paper try to present the in-process researches of the world and judge by the results and performed measures on the stone machining. There are many questions about stone milling, especially the effects of technological parameters on the surface roughness. The authors are looking for the answers of these questions and the correspondence between the investigations to prepare monitoring of the parameters in the machining system. The authors present possibilities from the five months long literature review and other investigating scopes. This paper is focused on the granite material's machining and adumbrates the possibility of later granite milling tests using parameters of granite grinding.

2. Investigating of parameters which influence the stone's surface roughness

2.1 Influential parameters on surface roughness

The stone's properties are distributed differently owing to the heterogeneity. During the machining that causes fundamental problem thus stone machining needs continuous and accurate observation. Therefore the rate of heterogeneity, the properties of stone's components (physical, mechanical and fracture) influence the achievable surface roughness. Widely investigated parameter is the grain size, which has an important role in the discrimination of different granite types.
The most important components of granites:

- quartz;
- feldspar (determines the colour of the granite), plagioclase;
- dark rock-formings: muscovite, biotite, amphibole.

The main components are quartz and feldspar their percent quantity influence the surface fractures and cracks.

Naturally the achievable surface roughness is affected by the technological parameters too. These parameters are the feed rate, depth of cut, cutting speed, furthermore the applied tool and the machining tool's parameters. Most of the presented studies in this paper investigate the effect of the composition and technological parameters on the surface roughness.

2.2 Sawing of granites. Influence of texture and mineralogy and other parameters on the surface roughness

Ribeio et al. in 2007 and 2010 published two overall studies about the correlation between surface roughness and the technological parameters. Ribeiro et al. in both cases judged by series of experiments in empirical way on changing of surface roughness. The summary of these studies are announced below.

Ribeiro et al. in the study in 2007 [1] investigated the effect of the texture and the mineralogy on the cutting speed while examined the surface roughness. First they determined the composition of the selected granites what is necessary to analyse the effects of the components during the investigations. Then Knoop hardness, deep abrasion and Amsler wear were measured. After that, they performed machining with different cutting speed, and they finally found out the roughness with profilometers. This process was followed by evaluating the measured values, and determining the quartz's (dispersion and percent quantity) effect on cutting speed, wear and abrasion. They presented the influential parameters of cutting speed compared two types of granites. These parameters were the heterogeneity of grains (different sizes and shapes, distribution and percent quantity), and the relation of the components (e.g. interlacing between quartz and feldspar grains).

Later, in 2010 [2] other five different granites were investigated. This paper focuses on the correlation between the surface roughness of the stone and coefficient of dynamic friction. They observed the sawing of stones like the previous article. The characterisation of stones was performed by the examination thin sections and Knoop hardness, deep abrasion and Amsler wear ere also measured. Then they collected data with profilometers to describe the roughness and analysed them with PC.

It can be determined that the increase of coefficient of dynamic friction increases the surface roughness. They investigated the roughness to determine the volume of material to be removed by polishing. The conclusions of the authors are below:

- the mineralogy has a significant influence on the surface roughness;
- there is not any relationship between the rougness and the deep abrasion;
- there is correlation between slab roughness and wear resistance, Knoop hardness and coefficient of dynamical friction.

2.3 Relationship between surface roughness and microharness, microbrittleness

Several international studies have dealt with the relationship between surface roughness and microhardness, microbrittleness properties of different types of rocks. There is an obvious correlation between the two parameters by the theory. By J Xie's investigations [3] it can be established that the machining force and the surface roughness have a good relationship with the microhardness's values but this correlation does not consist with the microbritleness. Surface roughness is influenced by distribution of diamond grains. These results are not related to the stone's properties, but they can help in the tool selection. Researchers demonstrated with measures that the minimum surface roughness of granite is more than metal's, glass's or quartz's roughness with the same parameters during the machining. The reason of this difference is the difficulty of stone machining.

There is not any relationship between surface's shining and microbritleness. Shining is an accompanying effect of the good surface roughness and influenced by the mineralogy and texture. The mikrohardness influences the required power and the tool's lifetime.

J. Xie machined four different granites (with different properties) and investigated the process. After determining microhardness and microbrittleness he compared the results (Fig. 1. and Fig. 2.).

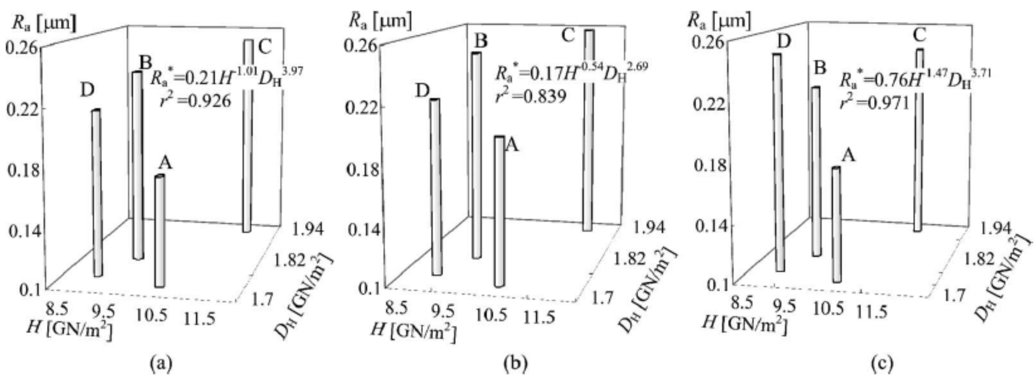

Fig. 1. Surface roughness (Ra) versus microhardness (H) and its average deviation (D_H); (a) v_f=0,5 m/min, (b) v_f=0,75 m/min, (c) v_f=1,5 m /min (from J. Xie (2010) [3] Fig. 7. on p. 7.)

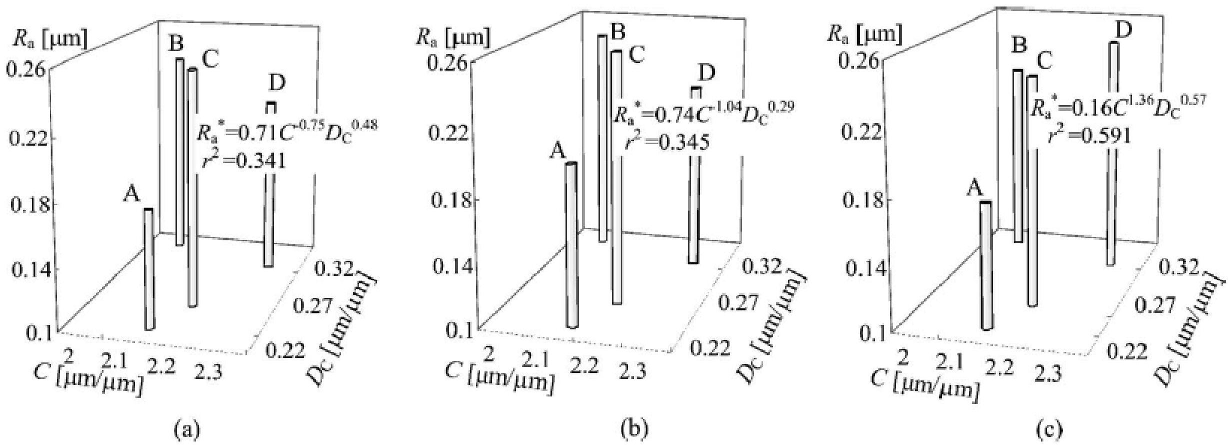

Fig. 2. Surface roughness (Ra) versus microbrittleness (C) and its average deviation (D_C); (a) v_f=0,5 m/min, (b) v_f=0,75 m/min, (c) v_f=1,5 m /min (from J. Xie (2010) [3] Fig. 8. on p. 7.)

The author also published an empirical formula for calculating the achievable surface roughness from the technological parameters.

3. Investigating the grinding process

3.1 The necessity of examination

To reach the suitable surface roughness the grinding of stone products is indispensable. It makes the surface more shiny or aesthetic and helps ensure usability. The machining process consists of several steps. During the machining diamond tools with different grain sizes are used by practical way. The previous processes are completed in such a way, that to rest the minimum material to remove with grinding and polishing.

3.2 Investigation of ablation mechanisms of granites with diamond tools

H. Huang et al. [4] investigated the glossy granite surface (published in previous articles). Their work's aim was to determine, how this some micrometers thin film can be examined. Most of their researches were made by scanning electronic microscope on the two different types of granite after grinding performed by six dissimilar resin-bounded diamond tools. The machining demonstrated the correlation between surface roughness and size of diamond grains. Smaller diamond grains decreased surface roughness's value. Under a certain grain size they could perform really glossy surface. This shiny film is the result of the ductile flowing caused by the grinding. Thus the ductile-mode removal marked the fine grinding process while brittle-mode removal is typical during the coarse grinding process. Machining with this process (using small diamond grains) can guarantee the adequacy for one of the main quality criterions, the suitable surface shininess. With their examinations they determined that the roughness and the shininess (there is a relationship between them) are not related to the conditions of grinding. These parameters are related to the grain size. Workpieces with high roughness values are scratched and cut by the grains, while the grains plow the surface by decreasing the grain size and workpiece’s roughness. Thanks to multidirectional grinding the paths generated by process can be hid.

3.3 Interactions between diamond tools and granite

H. Huang et al. [5] unveiled a widespread delusion which said that the interfacial surface’s high temperature causes ductile flow of granite. Ductile flowing has an important role in decreasing surface roughness but the main causing is not the temperature. There are some SEM micrographs of surfaces with ductile flowing on fig. 3.

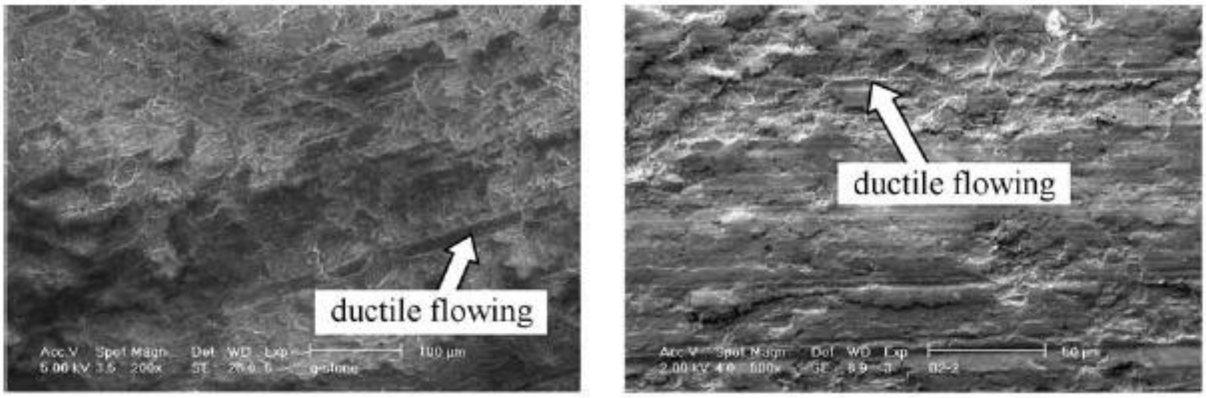

Fig. 3. SEM micrographs of ductile flowing (from H. Huang et al. [4] Fig. 2. on p. 4.)

According to assumptions, the temperature has to be as high, as it may cause ductile flowing in the granite and the tool but they are heat-stable enough to prevented from heat’s effect. The authors also noticed that the temperature did not have extremely high values during the examinations. The highest value was lower than 100 °C during an extreme machining (50 seconds grinding continuously only one part of the stone). They measured some flashing temperature-peaks which are dangerous in terms of the tools wear but there are not any detailed observations.

It means that the ductile flowing is the result of machining with small grain sized tools, and in this way the shiny surface is more reachable more easily.

4. Investigation of stone milling

The aim of this paper’s authors is to investigate stone milling technologies, what is the focus of this literature review’s summary. However engineers have improved machines for stone machining, there are not too many publications about this part of mechanical engineering. Stone milling’s kinematic and tool’s properties can be parallel with stone grinding’s properties and tools. While the other stone machining technologies are investigated in terms of surface roughness, we have not any examination’s results on stone milling.

4.1 Investigating of diamond tool's micro-geometric wear

The parameters that can influence surface roughness are machined material's properties and the machining tool's characteristic. Thus investigating tool's wear is also necessary. W. Polini et al. [6] invented a test protocol to determine tool's micro-geometric wear and they performed their examinations on stone milling processes. They found out that there is a relationship between surface roughness and abrasive grain's size of the tool and roughness is influenced by machine's parameters, adjusted technological parameters. They observed the correlation between tool's wear and achievable surface roughness.

5. Research possibilities in optimization and estimate of surface roughness

This paper's previous parts show that many examinations were done in the last ten years internationally. This research's aim is to collect information about the relationship between machining process and surface roughness. From studies, it is apparent that research's results (equations or models) are earned in an empirical way because of the many differences in texture's properties of different stones. There are not any general models for groups of stones that would work safely. And manufacturing engineers neither have any models for stone milling processes. This paper's authors want to create a general model that can work with all stone types or big stone groups and gives information about surface roughness and technological parameters. It's important for manufacturing engineers who work with NC machining tools. We collected trends for investigating and described an examining system.

5.1 Grinding process's adaptation on milling process

In the third chapter the current investigations in stone grinding are presented in details especially in terms of estimating the surface roughness. In the automatic stone machining the grinding tools and milling tools are similar in their structure. Both of the tools are built from a metal core and a part which performs the machining directly. This part has a big extension in case of grinding, which involves the whole disk. The milling tool has the same part but it involves many smaller rectangular parts on its frontal or lateral areas. These smaller parts are segments, built from binder (as a matrix material) and diamond grains [7].

A possible investigating area is the grinding technology's adaptation on NC controlled automatic milling processes. Thereunto determining theoretical relationships is necessary and performing many examinations of technological parameter's effect on milling processes is also important.

5.2 Investigating empirical regularities from experiments

The researchers and manufacturing engineers determine the relationship between technological parameters and surface roughness, tool's life or manufacturing cost in stone machining (sawing, cut, drilling) by performing different examinations. They work this way in stone milling too, but it causes many problems. First of all there are only a few NC controlled machining tools for researching in the world because these machines are usually used in industry and manufacturers can't spend time on examinations. Thus improving a test system, which includes other measuring equipment (examine physical, mechanical, fraction properties) can helps save time and researchers can conclude from less observation by using it.

5.3 Possibility of the machining and measuring system's building up

After the end of researches written in this paper's first part the authors will examine the correlation between technological parameters and surface roughness in stone milling. This relationship will observe on some different stone types. The results can be processed well, if there is a complex machining and measuring system which ensures the same machining conditions during the investigating period and can collect, store, and classify the parameters and data during the machining. Thus a carefully built machining and measuring system is required to perform stone machining tests reliably (Fig. 4.).

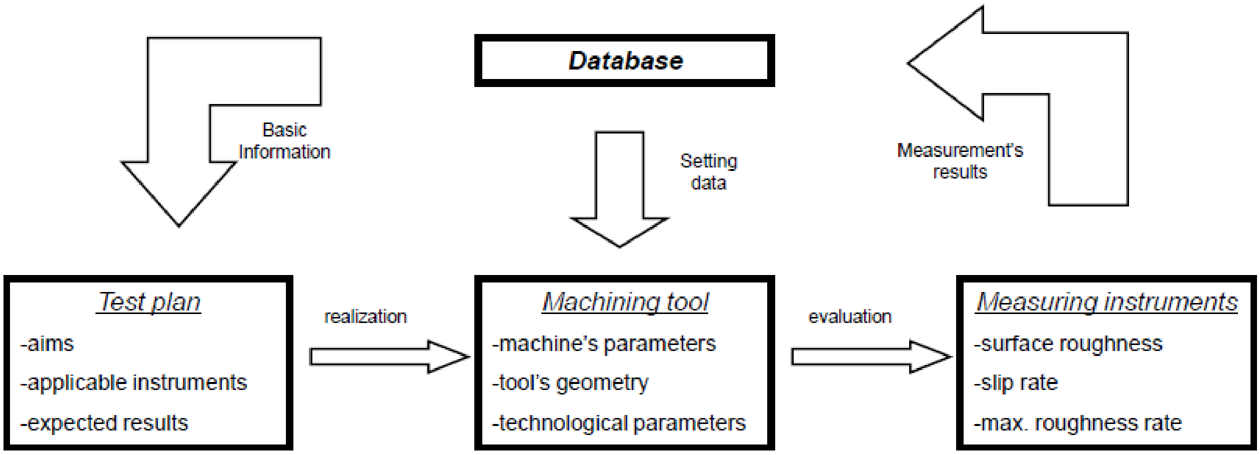

Fig. 4. Machining and measuring system

The recommended system's basic module is a database, which contains the parameters of machine tool (in this case a NC controlled stone machining tool), applicable tool's geometries, materials and feasible technological parameters. By using this database can be an examination series assembled which is necessary from theoretical hypothesis. Relationships between parameters can recovered from the database and by using them a general model can be worked out.

Machining tools used for stone milling examinations have to be very stiff and other requirements need to be met such as appropriate performance and repeatability.

The aim of the researches is important in terms of the measurement system. To investigate the relationship between technological parameters and surface roughness it is important to have an appropriate profilometer (or roughness-measurer) which can measure the milled surface (average roughness, roughness's peaks, maximum roughness's value). Mobil profilometers are recommended because the measured products have big extensions and mass but we have to take care on the range of measurement. There is a relationship between surface roughness and slip safety. To determine the slip safety factor examiners use a pendulum system with a range of measurement. These ranges have to be matching. Thus during the building of the measuring system researchers have to solve a complex problem system. To build the measuring system they need to have a data recorder too. A common database can help to determine the regularities.

6. Conclusions

This paper's aim is to present the investigations of today about the stone machining in the world especially examinations about surface roughness. Presenting the influencing parameters, specifying the applied technologies and drawing up investigating possibilities make a basis to continue the observation.

We can see that the mineralogical composition and the diamond grain's sizes have accentuated roles in these parameters. Effect of temperature is unimportant. Improvements are feasible by more observations on tools, which can help us reach the suitable surface roughness easily.

The second part of this paper presents some investigating possibilities for other researchers in stone machining and determines the needful technological background for effective examinations on the surface roughness in case of different stone types.

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