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CORRELATION BETWEEN MICRO-CUTTING AND STATIC INDENTATION

Miloš Pjević[1], Mihajlo Popović[2], Radovan Puzović[3]

Abstract: Micro-cutting as a material processing process is completely different from classic macro cutting. Defining the mechanism of micro-cutting is one of the goals followed by the world's researchers. One of the most common approaches so far is the identification of micro-cutting with the static indentation of an indenter, which is the subject of this paper. In the case of micro-cutting of brittle materials, where the presence of its destruction during processing is pronounced, by static indentation it is possible to establish which types of cracks occur inside the material. Another important thing is that with this method it is also possible to define the critical penetration depth below which brittle materials can be processed by the mechanism of plastic deformation.

Key words: Critical penetration depth, Micro-cutting, Brittle materials, Static indentation.

1 INTRODUCTION

With the history of over 100 years old, cutting technology represent one of the most common used technics in the processing industries. Accumulated knowledge during this period, provided the possibility to interduce such algorithms for cutting parameters. Outputs are cutting parameters in the form of cutting depth, speeds and feeds, and also adaptive tool path which maintains constant angle of cutting. The result is more stable cutting with less vibration of the tool and part setup, and also higher tool life. All of this cannot be possible without detailed knowledge of the mechanism of the macro-cutting.

With exponential increase of the demand defined by the market, more often micro-cutting must be applied during the processing process. With dimensional

[1] dr Miloš Pjević, Assistant Professor, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia, mpjevic@mas.bg.ac.rs
[2] dr Mihajlo Popović, Associate Professor, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia, mpopovic@mas.bg.ac.rs
[3] dr Radovan Puzović, Full Time Professor, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia, rpuzovic@mas.bg.ac.rs

reduction, it is established that well known mechanisms of the macro-cutting cannot be applied on the micro-cutting. In addition, machining the parts with brittle properties, new cutting mechanism must be defined.

Although research on this topic has been going on since the mid-seventies of the last century [1-4], in the last years, big breakthrough is achieved in the field of micro cutting of the brittle materials [5-12]. One of the proposed mechanisms that describes phenomenon that occurs in the micro cutting process is based on the static indentation.

2 MICRO CUTTING MECHANISM BASED ON THE STATIC INDENTATION

The static indentation is one of the used methods that can be used for possible identification of the phenomenon that occurs during micro-cutting.

The method consists of two phases. The first phase represents the indentation of the diamond tool (indenter) into the workpiece, while the second phase refers to the microscopic observation of the footprint formed on the surface of the workpiece (Fig. 1).

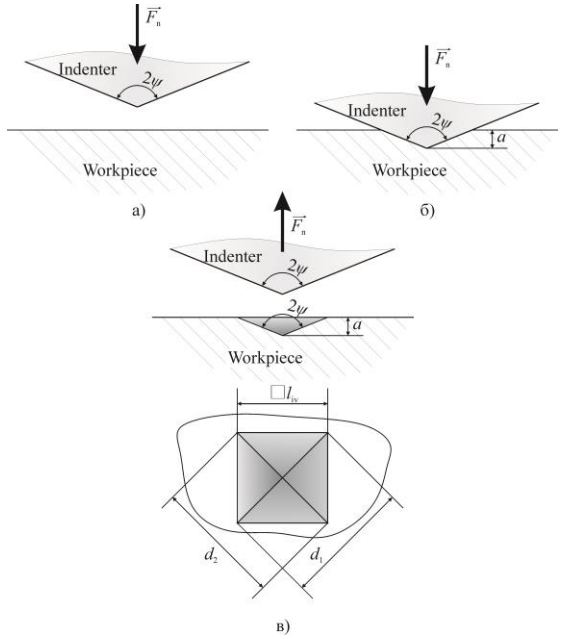

Figure 1. *Static indentation process*

In this method, only the normal force exerted by the indenter on the workpiece is present. Appropriate results can be obtained with this method, however, not including the tangential component of the cutting force leads to the fact that it is not possible to precisely define the micro-cutting mechanism of brittle materials with certainty. On the other hand, with this method, it is possible to roughly determine the range in which cracks can appear under the action of the appropriate pressing force, and it is known that cracks are an inevitable phenomenon in the process of the formation of chips due to the processing of brittle materials.

Depending on the value of the indentation force, i.e. the depth of penetration of the indenter, three phenomena are possible on the surface of the material (Fig. 2).

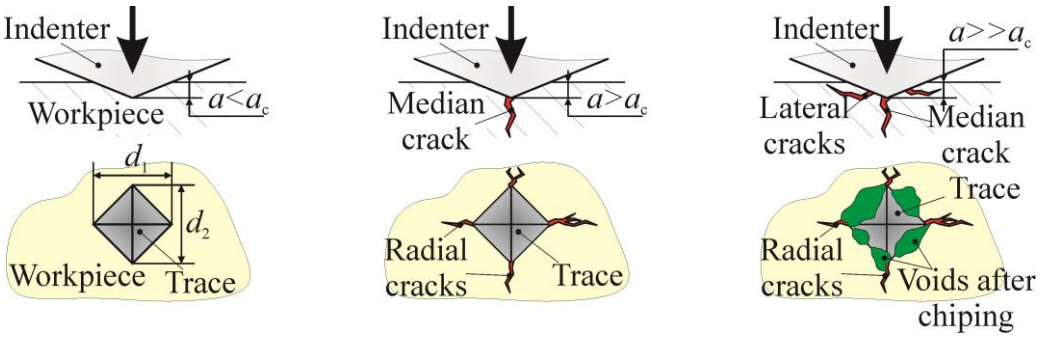

Figure 2. *Static indentation process*

The first case represents a trace that was created without the presence of material destruction. In the next case, with an increase of the penetration depth, the formation of cracks inside the material can be observed, while in the last case, separation of the material was also observed.

3 EXPERIMENTAL SETUP

In order to evaluate proposed mechanism that is based on the static indentation, experiments were conducted on the micro hardness tester presented in Fig. 3.

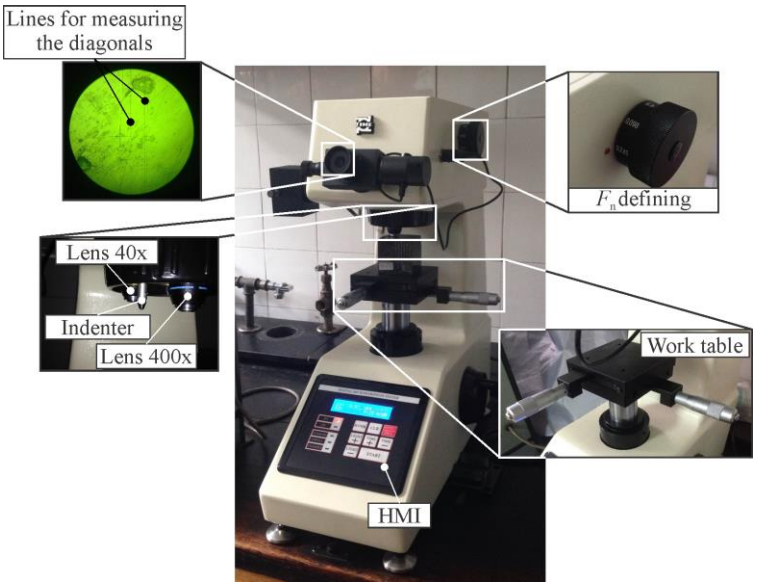

Figure 3. *Experimental setup.*

Material that is tested is marble Plavi tok. To determine critical penetration depth, below which there is no presence of the cracks in the material, indentation force was varied in the range from 0.098 [N] up to 9.807 [N]. Every test is repeated four times for dwell time T=0 and T=15 [s].

4 RESULTS

In the Fig. 4, there are some of the traces made by the indenter. At lower penetration depth there is a clear sign that there no evidence of the crack formation within the workpiece. This shows that brittle material can be machined without its destruction in the so-called ductile mode. When transition from ductile to brittle fracturing mode occurs, within material, formation of the median, radial and lateral cracks is present.

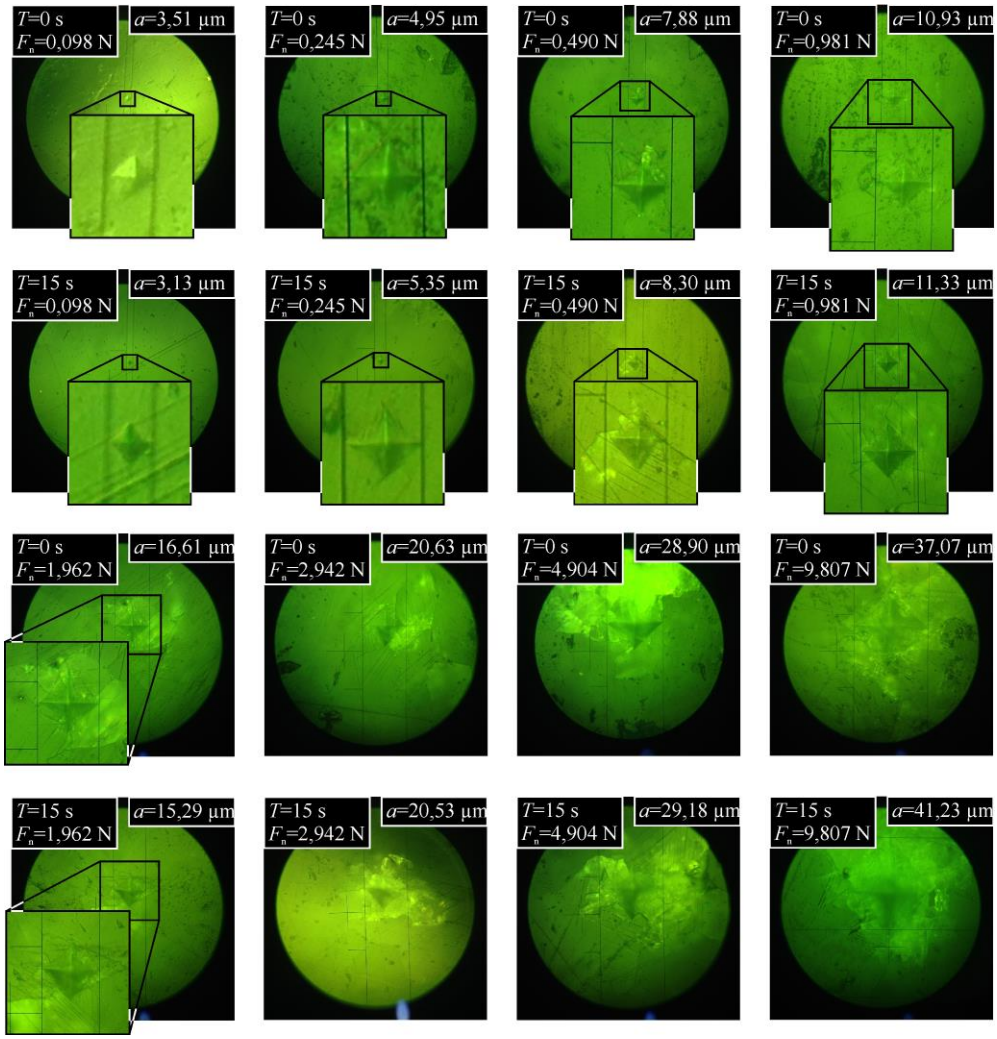

Figure 4. *Formed traces by the indenter.*

In Figure 4, it is clear that case 1 can be seen at lower penetration depths (5.73 µm). At this stage, there are no signs of cracking within the material. In case 1, the material is purely plastically deformed, i.e., the depth of penetration has not exceeded its critical value. Exceeding the critical penetration depth, case 2 occurs, in which the process of formation of cracks (median and radial) is noticeable. Case 2 is within the limits of the penetration depth of 11.33 µm. Beyond this depth, case 3 occurs, in which

the previously mentioned cracks are joined by lateral cracks that lead to the separation and destruction of the material.

When compared with single grit micro-cutting, presented in the Fig. 5, it can be told that the same cracks appear during static indentation, as well as possibility to obtain ductile mode.

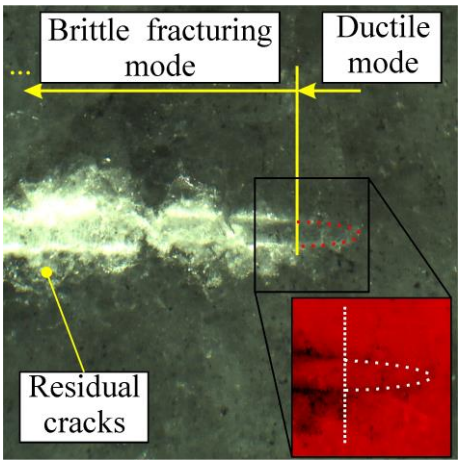

Figure 4. *Formed traces by the indenter.*

5 CONCLUSION

Conducting static indentation experiment on the brittle material, can be used in order to evaluate the types of the cracks that occur within the material itself during micro-cutting in the brittle fracturing mode. In addition, critical penetration depth that separate brittle fracturing mode and ductile mode can be established. On the other hand, static indentation can be also used to determine, is there presence of the ductile mode when machining brittle materials.

One of the downsides of this kind of mechanism proposal, is that there is no presence of the tangential components of the cutting force that can further induce crack growth within the material, and also orientate their growth direction.

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