COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

Elimination of edge-chipping phenomenon during rotary ultrasonic drilling

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Advanced materials such as ceramics, composites and other materials with superior properties are increasingly used in industries such as aerospace, automotive, electronics but they are also used in medical applications. Mechanical properties of such materials are characterized by specific properties such as high hardness, excellent wear resistance and brittleness. However, these properties usually cause difficulties and complications in machining and obtaining the desired shapes and dimensions of the products from these materials. As mentioned, these materials are hardly machinable by conventional machining processes. For these reasons, it is very important to develop efficient machining processes that will ensure the quality of the machining process and the energy and cost efficiency of machining.

One of the advanced processes used for drilling holes into the above mentioned materials is rotary ultrasonic drilling (RUD). This process can be classified as a hybrid process combining grinding process using diamond tool that simultaneously performs axial vibrations with frequency at the ultrasound level. The RUD process is characterized by sufficiently high removal rate while cutting pressures remain low with relatively small surface damage and strength degradation. Significant attention is paid to the processes and problems arising during the rotary ultrasonic drilling from both the theoretical and experimental points of view. One of the important problems that has to be solved in the RUD process is the formation of undesirable phenomenon called edge-chipping (Fig. 1).

During a hole drilling, the hole bottom thickness is changing and consequently an annulus plate area of the drilled hole bottom is subjected to transition through the resonance states. This resonant state can be considered as one of the important effects that leads to occur the ”edge-chipping“ phenomenon. As a consequence of this process, when the drilling tool is finishing the hole, the bottom edge of the hole is degraded by breaking the edge. In order to eliminate this phenomenon or to reduce the size of the edge damage of hole, it is necessary to examine the stress-strain state that arises as a result the ultrasonic vibration, workpiece structure and shape parameters of the drilling tool. The maximum stress states are analysed in critical zones of the drilled hole. The dependence of equivalent stresses on the edge radii of drilling tool and on the change in the bottom thickness of drilling hole is investigated.

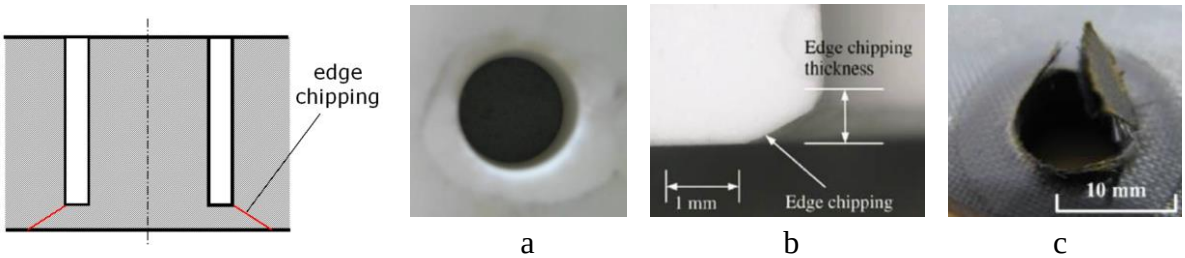
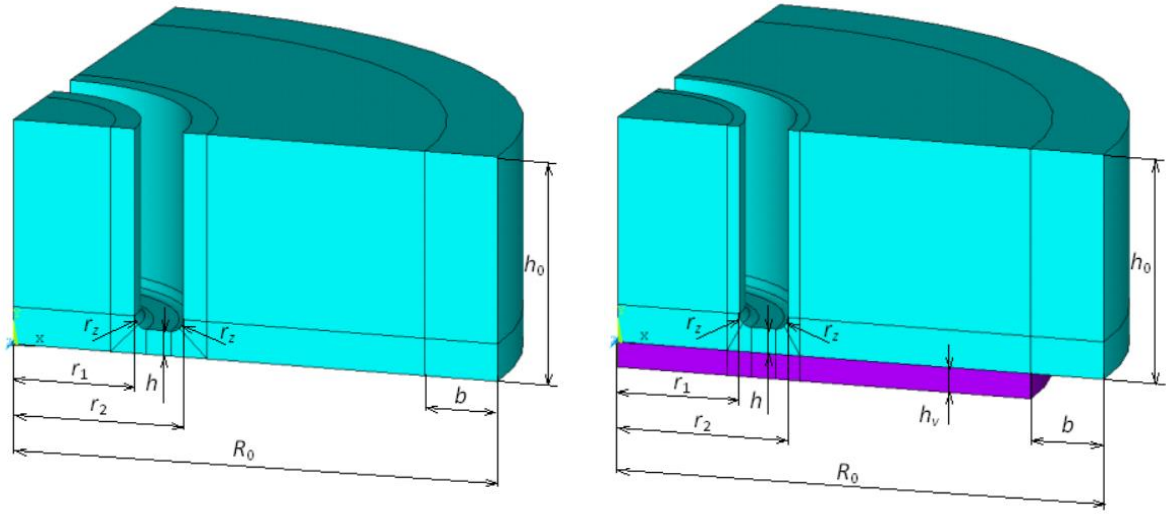


Fig. 1. Typical cases of edge-chipping formation (a - [4], b - [1], c - [2])

The edge-chipping phenomenon is investigated in two levels. The first approach is based on an investigation of the influence of the geometric parameters of the drilling tool [3] on the stress-strain state that occurs in the workpiece. The second approach is focused on the purposeful change in the workpiece structure, i.e. the structural modification of the workpiece by means of reinforcing layer (Fig. 2) on the lower surface of the workpiece.



a b

Fig. 2. Model for simulation of RUD process: a - without reinforcing layer, b - with reinforcing layer

Rotary ultrasonic drilling process is a complex process with a large number of input parameters and variables that have to be taken into account in stress-strain analyses. The finite element analysis of RUD process is used to the prediction of edge-chipping phenomenon. The numerical simulation of drilling process using the RUD process are realized using the finite element models corresponding to models shown in Fig. 2. The structural modification effects based on additional reinforcing layers on the stress-strain states and prediction of "edge-chipping" phenomenon occurring during RUD are analysed in this paper.

Acknowledgements

The work was supported by the grant project KEGA 029STU-4/2018 and institutional project IP MTF 1603/2017.

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