Influence of Tool Wear on the Quality of the Newly Formed Surface in the Drilling of Wood Composites

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Abstract – The geometry of a drilling tool largely affects the quality of the newly formed surface. When drilling through a composite panel, the hole edge quality on the outlet side is significantly worse than on the inlet side, so the choice of the appropriate tool geometry is crucial. Even if the tool geometry is correct, tool wear also has a strong influence on the quality of the newly formed surface of the holes. With the tool wear, the force in the direction of drilling and torque around the axis of drilling are increasing which can affect to the delamination of particle board on the outlet side. The proposed model for hole edge quality prediction on the outlet side was tested on an experimental model where the cutting forces and torque in the drilling direction were measured, and the quality of the newly formed surfaces was evaluated every 180 holes using a visual method.

drilling / cutting forces / particle board / surface / delamination / quality of the edge

1. INTRODUCTION

In the furniture industry, furniture is most frequently made from surfaced, composite panels of medium (MDF) and low (PB) density. The drilling of holes through composite panels presents considerable problems in the assurance of a high quality edge on the outlet side of the hole. If the loads involved in drilling the hole through the composite are higher than the delamination value of the composite, the composite delaminates on the outlet side is most frequently unacceptable. Drilling loads depend on the technological parameters of machining, i.e., feed rate, tool rotation speed, tool geometry, and specimen properties. The structure and composition of the composite in particular have a strong influence on the tool wear as well.

Today, composite panels can contain a large portion of recycled old furniture, and thus also contain a relatively great amount of particles that are not of a wood and lignocellulose origin. Most frequently, these are ground metal structural elements (screws, door hinges, metal guides, etc.) of the recycled furniture or sand and stones which were introduced into the composite raw material during transport and handling of waste furniture before the recycling process. In the event that during the process of drilling the tool comes in contact with such a foreign body in composite panel, the tool is instantaneously damaged, which considerably changes the tool geometry and increases the thrust force, consequently affecting the composite delamination on the outlet side of the hole. In the case of automated production it is therefore reasonable to use a tool monitoring system, and if the tool is damaged, stop the production until the damaged tool is replaced.

Many researches have been conducted to determine the optimum technological parameters of drilling and their influence on the delamination of the layer on the outlet side of the hole can be found in literature. Most frequently the authors used MDF boards in their research (VALARMATHI *et al.*, 2012; PAULO DAVIM *et al.*, 2008; GAITONDE *et al.*, 2008 and PALANIKUMAR *et al.,* 2009). However, in 2013 a study of the analysis of drilling technology parameters in drilling particleboards (VALARMATHI *et al.*, 2013) was published, where thrust force was also measured and analysed. The studies take no consideration of tool wear which, however, strongly and immediately affects the magnitude of thrust force in drilling.

2. EXPERIMENTAL SYSTEM

The measurements were performed using a three-axis, experimental CNC machine tool in the Laboratory of Mechanical Processing Technologies at the Biotechnical Faculty of the University of Ljubljana. The rated power of the tool spindle of the CNC machine tool is 3.2 kW at a nominal speed of 18000 rpm. A clockwise rotating tool intended for drilling holes, produced by Leitz, with designation 34077, 8 mm in diameter and with maximum drilling depth of 70 mm was used for drilling into a white, 18 mm thick, laminated particleboard. A cyclic drilling programme was used to drill series of 180 holes into the panels of 500 mm x 700 mm in size. The distance between holes was 15 mm, the tool feed rate was 1800 mm/min, and the tool speed was 6000 rpm. After each completed series of drilling, the thrust force was measured in the direction of drilling axis on the previously prepared five specimens, which were subsequently also used to determine the particleboard delamination factor. The thrust force was measured by a three-axis, piezo-dynamometer by Kistler, with designation 7292, which was connected to a Kistler 5019 amplifier. The amplifier output was connected to a multifunctional PCI interface with designation NI USB 6351, made by National Instruments, which made it possible to store force measurements with the sampling frequency of 100 kHz for further analysis. The measurement system block diagram is shown in *Figure 1*.

Figure 1. Measurement system block diagram

3. RESULTS OF MEASUREMENT

Equation 1 was applied to determine the particleboard delamination factor for the specimens used to measure the thrust force. Each specimen was photographed and the area of particleboard delamination was measured using the photo processing program, which is shown in *Figure 2*.

$$F_d = \frac{d_d}{d} \tag{1}$$

F_d - delamination factor
d_d - diameter of the circle drawn around delamination area [mm]
d - hole diameter [mm]

The results of calculated delamination factors are recorded in *Table 1*.

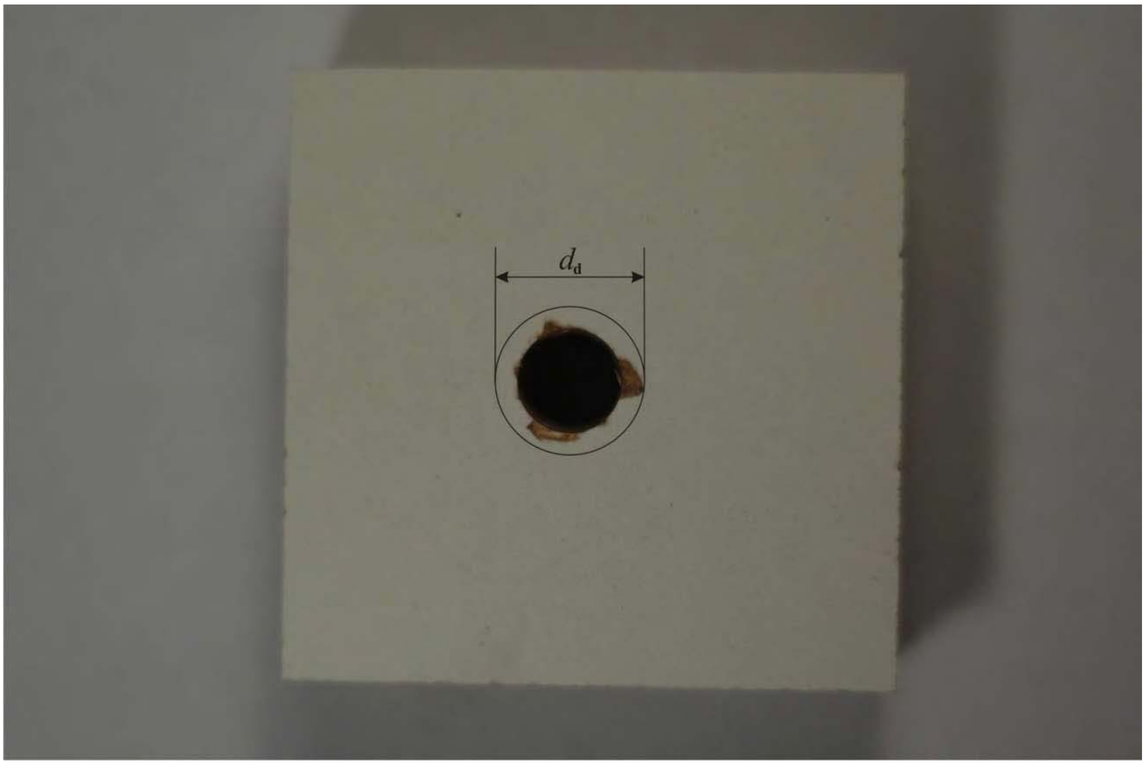

Figure 2. Graphic presentation of determining the delamination factor

Table 1. The measured composite delamination factor of five test specimens after N drilled holes

N	185	1110	2220	3330	4440	5550
s1	1.00	1,21	1,24	1,31	1,44	1,28
s2	1.00	1,30	1,36	1,25	1,26	1,33
s3	1.00	1,24	1,25	1,45	1,32	1,26
s4	1.00	1,00	1,15	1,22	1,22	1,35
s5	1.00	1,16	1,43	1,20	1,35	1,34
	1.00	1,18	1,29	1,29	1,32	1,31

Figure 3 shows the time course of the average of five measured thrust forces which were measured in five specimens after the completed cycle of drilling 180 holes. However, the time course of the force, on the assumption of constant feed rate, shows that during the phase of drilling the force reaches two peaks, and both peaks represent structural properties of particleboard or its density profile. Thus, the two denser layers on the surface of particleboard have a greater specific cutting and thrust force. The somewhat lower first peak, as compared to the second one which is on the outlet side of the hole, can be attributed to the geometry of the tool used which was intended for drilling holes and therefore had a very small point angle. The second force peak which is encircled in *Figure 3* occurs in the phase of drilling the bottom layer of particleboard, and in the event that it exceeds delamination value of the layer, it causes delamination of the particleboard on the outlet side of the hole. *Figure 3* also shows the influence of tool wear on the magnitude of thrust force; i.e., after 5550 drilled holes the thrust force is increased by 84.2 %. Figure 4 presents the dependence of thrust force and the delamination factor on the number of drilled holes. The measurements show that the maximum permissible thrust force which has no influence on the delamination of outlet hole is 60 N.

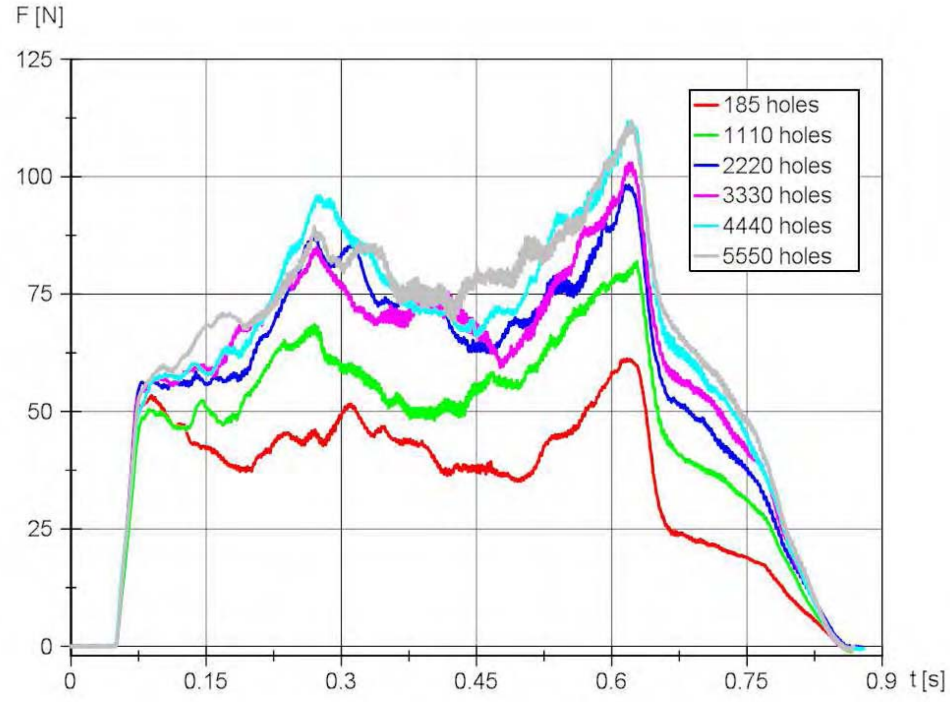

Figure 3. Measured averages of force in the direction of drilling

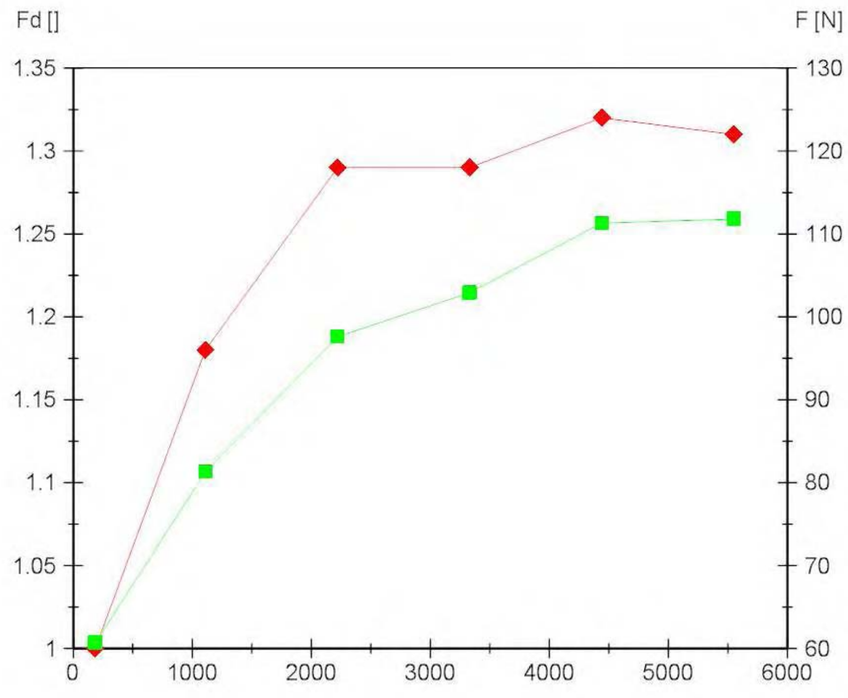

Figure 4. The course of delamination factor F_d (red) and maximum thrust force F (green) of drilling depending on the number of drilled holes

4. CONCLUSION

The results of measurements show a relatively good relation between thrust force magnitude and particleboard delamination factor, which also means that the maximum value of thrust force can be used to determine the surface quality on the outlet side of the hole or the degree of particleboard delamination. It is assumed that similar results can also be expected in a different evaluation of the particleboard quality or the delamination degree on the outlet side of the hole and torque around the axis of drilling. The results of preliminary measurements indicate the possibility of using the thrust force measurement as a starting point in the regulation of adapting the technological parameters of the feed rate or the rotational speed of the tool to the optimum, or still the satisfactory degree of composite delamination on the outlet side of the hole.

5. REFERENCES

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