

FRETTED PANELS MADE OF PLYWOOD AND BEECH WOOD. COMPARISON AND QUALITY EVALUATION BY STEREO MICROSCOPY

Iulian PAIU

PhD student - TRANSILVANIA University of Brasov – Faculty of Wood Engineering
Address: B-dul Eroilor, nr. 29, 500036, Brasov, Romania
E-mail: iulian.paiu@unitbv.ro

Camelia COȘEREANU*

Prof.dr.eng. - TRANSILVANIA University of Brasov – Faculty of Wood Engineering
Address: B-dul Eroilor, nr. 29, 500036, Brasov, Romania
E-mail: cboieriu@unitbv.ro

Abstract:

The present paper is an analysis at the microscopic level of the quality of the edges obtained by CNC milling of fretted panels, considering also the processing times resulted for routing these ornaments on two different materials, namely 12mm beech wood panel and 4mm beech plywood (3 pieces that compose the whole model by combination). In the experimental work, a single setup of the milling parameters was considered, and the analysis of the quality of the cut edges was conducted through measurements of the torn fibers for different inclinations of these edges relative to the wood grain direction. The results show that the quality of the edges in case of CNC milling the plywood is better than for the beech wood panel, whilst the processing time for beech wood panel is shorter than for the three pieces of plywood.

Key words: fretted panels; CNC router; stereo-microscopy.

INTRODUCTION

Fretted panels are used for room dividers, furniture decorations, interior design or small decorations. These types of ornaments are both floral and geometrical ones and have their historical background in the Islamic culture. They are characterized by symmetry and mathematical rules, or by shape grammar rules, as was outlined in a study showing that computer and CAD applications has the main control over geometric patterns, which may be grouped as patterns derived from triangle, rectangle and pentagon (Cenani and Cagdas 2006). The mathematical rules and the role of geometry in Byzantine, Roman and Gothic ornaments found in the architecture and architectural decorations were studied by other researchers, who created grids to reconstruct patterns of the ornaments based on circular and interlaced shapes (Majewski 2014).

The complexity of the different approaches of ornamentation in architecture is explained by Moussavi's classification of the ornament based on depth material or effect (Moussavi 2007). (Schimek et al. 2008) have explored the ornamental patterns which can be used to enhance materials characteristics in low-cost building envelopes. They have used cross-laminated timber and developed a parametric design framework for the assembly, applying rules of ornamental geometry to a parametric controlled structural mathematical model and employing the MCAD-software tool SolidWorks.

Besides analyzing the geometric shapes and the patterns of cut ornaments, several studies are oriented to the routing process investigation in terms of processing parameters used for milling the wood. The criteria taken into consideration for optimizing CNC wood milling operations by a group of researchers were minimum machining time and optimal surface quality, thus covering both productivity and quality goals at the same time (Krimpenis et al. 2014). Among these, many researchers consider that wood surface roughness is a crucial indicator of the quality of CNC processing parameters (Çakiroğlu et al. 2019, Hazir and Koc 2019, İşleyen and Karamanoglu 2019). Various species of wood (hardwood, resinous wood) have been used for testing the CNC processing parameters with spindle speeds in the range 10000rpm - 18000rpm, feed rate between 2m/min and 8m/min, depth of cut between 2mm and 6mm. Optimum parameters for spruce wood were found to be the spindle speed of 10000rpm and 5m/min feed rate (İşleyen and Karamanoglu 2019), and 18000rpm spindle speed and 7m/min feed rate for larch wood (Çakiroğlu et al. 2019), spindle speed of 17377rpm, feed rate of 2,012m/min, and depth of cut of 2,009mm for Cedar of Lebanon Pine (Hazir and Koc 2019). Satisfactory values for Ra roughness parameter have been obtained for beech wood with a spindle speed of 14500rpm and a feed speed between 2m/min and 2.5m/min (Pinkowski et al. 2012).

The study presented in this paper is a microscopically investigation of the quality of the cut edges of the ornaments obtained by milling processing on CNC router. Beech plywood and beech wood were used for the experiment, and a geometric pattern derived from triangle have been chosen for the experiment.

* Corresponding author

A stereo microscope NIKON SMZ 18 with a zooming range between 0.75 x and 13.5 x was used to investigate the quality of the cut edges. Measurements of the torn grains were taken on different inclination angles of the cut edges in relation to the wood grains direction. The next step is to measure the roughness on cut sections of the wood and plywood, in order to conclude which inclination is the most disadvantageous in milling the wood by CNC router.

OBJECTIVES

The objective of this paper is to present a stereo-microscopic evaluation of the quality of the cut edges of the ornaments obtained by milling processing on CNC Router. The materials used for investigation were beech plywood with a thickness of 4mm and a beech wood panel with a thickness of 12mm, both of them being processed at a spindle speed of 15 000rpm and a cut depth of 2mm. The paper presents measurements of the torn grains for the cut edges inclined with angles of 0°, 15°, 30°, 45°, 60°, 75° and 90° relative to the wood grain direction and a comparison between machining times and surface quality when using the two materials.

METHOD, MATERIALS AND EQUIPMENT

Panels with sizes of 370mm x 200mm made from beech plywood with a thickness of 4mm and beech wood with a thickness of 12mm have been subjected to milling processing on CNC router in order to obtain fretted panels with a geometric pattern (Fig. 1a).

Two variants of obtaining fretted panels with a thickness of 12mm and the geometric pattern presented in Fig. 1a were selected for the experiment. The first choice was to use plywood with a thickness of 4mm and to decompose the model into three geometric patterns (Fig. 1b, Fig. 1c and Fig. 1d), which, by combination, should result with pattern from Fig. 1a. The second choice was to use beech wood with a thickness of 12mm and process it directly with the pattern presented in Fig. 1a. Thus, a comparison between the two variants could be made in terms of minimum machining time and optimal surface quality.

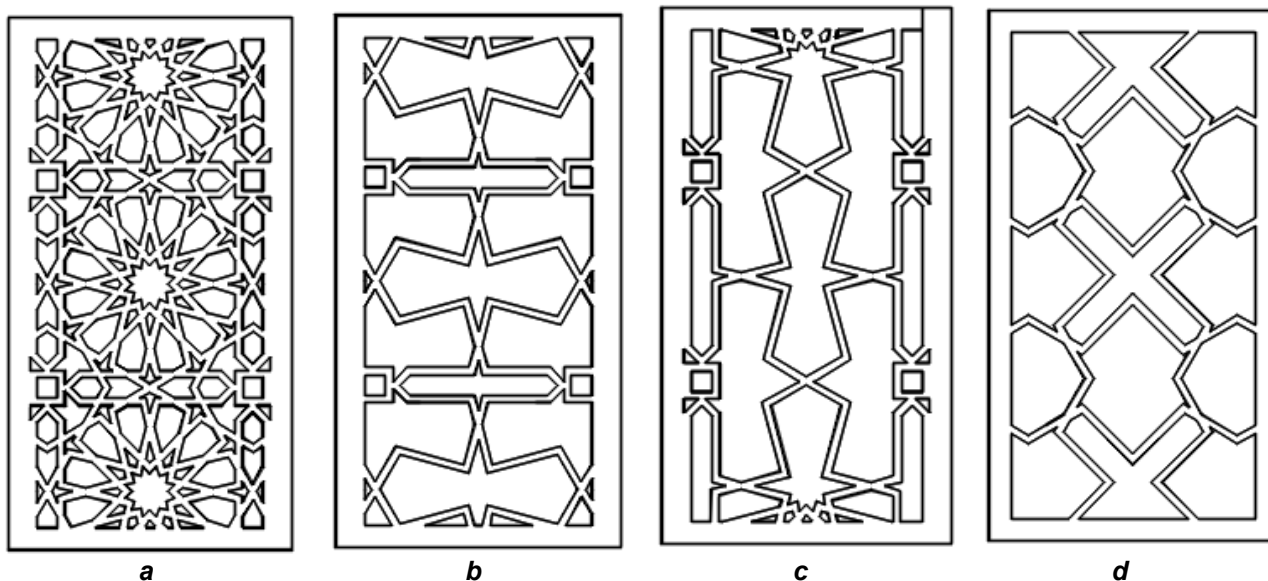


Fig. 1.

Fretted panel used as the model for the experiment (a) and the three parts (Part 1, Part 2 and Part 3) of the decomposed model (b, c and d).

Table 1

Samples and milling parameters set up

Sample type	Material	Sizes of the samples (Length x Width x Thickness), in mm	Spindle speed, in r.p.m.	Cutting depth, in mm	Feed rate, in m/min
Model-Part 1	Plywood	370 x 200 x 4	15000	2	2
Model-Part 2					
Model-Part 3					
Model	Beech wood	370 x 200 x 12	15000	2	2,5

The model of fretted panel was first drawn in AutoCAD based on the pattern derived from triangle (Cenani and Cagdas 2006), and then the model was decomposed in three different geometric patterns, as seen in Fig. 1b, c and d. The integral model from Fig. 1a is intended to be made at a thickness of 12mm from beech wood, and the decomposed parts of the model (Part 1, Part 2 and Part 3) at a thickness of 4mm each, from beech plywood, so to form, by combination, a whole panel with a total thickness of 12mm (Table 1).

The cutting parameters, such as spindle speed and feed speed have been chosen in accordance with the conclusions of the research made on beech wood (Pinkowski et al. 2012). The milling parameters' set up are presented in Table 1.

Integral Helical CMS milling cutter, with $Z = 2$ UPCUT DR and $D \times B \times L$ sizes of 3mm x 12mm x 40mm (Fig. 2) was used for CNC routing, as tool.

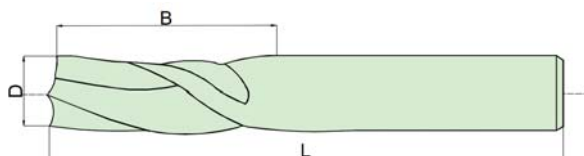


Fig. 2.
The tool used for the CNC milling of fretted panels.

The microscopic investigation was performed with the stereo microscope NIKON SMZ 18, with a zoom ratio of 18:1 and zooming range between 0.75x – 13.5x. In combination with 2x magnification of the objective and 30x magnification of eyepiece, the total magnification of the microscope is 810x, at a working distance of maximum 60mm (Fig. 3). The microscope is in the endowment of the Research Institute of Transilvania University of Braşov.



Fig. 3.
Stereo-microscope NIKON SMZ 18.

The CNC router used for processing the panels is presented in Fig. 4. The AutoCAD drawings were exported as .dxf files to CNC router and then have been processed using the parameters presented in Table 1.



Fig. 4.
CNC router used to process the panels.

The CNC router, ISEL GFV type, German production, has in its technical characteristics a maximum spindle speed of 15000rpm, so this maximum spindle speed was selected for processing the beech wood.

The panels resulted after milling on CNC have been visually analyzed and the details where torn fibers were observed have been marked in order to be subjected to microscopic measurements. The angles between the wood grains and the cut edges were measured under microscope with 4x magnification. The geometric pattern allows measurements of cut edges inclined with an angle of 0°, 15°, 30°, 45°, 60°, 75° and 90° against the wood grains.

RESULTS AND DISCUSSIONS

The fretted panels resulted after the milling processing on CNC router are presented in Fig. 5 for beech wood and Fig. 6 for the parts of the decomposed model, made from plywood.

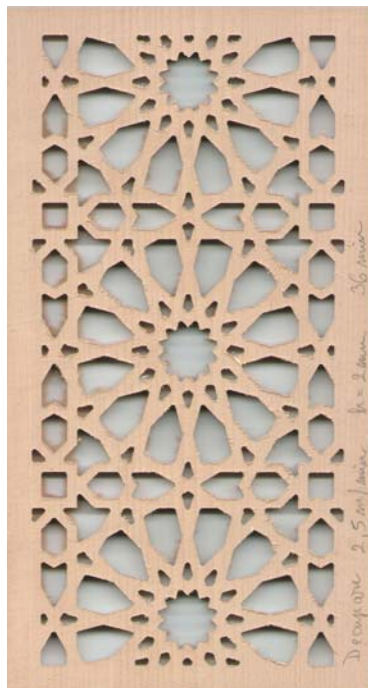


Fig.5.

Fretted panel processed on CNC router from beech wood.

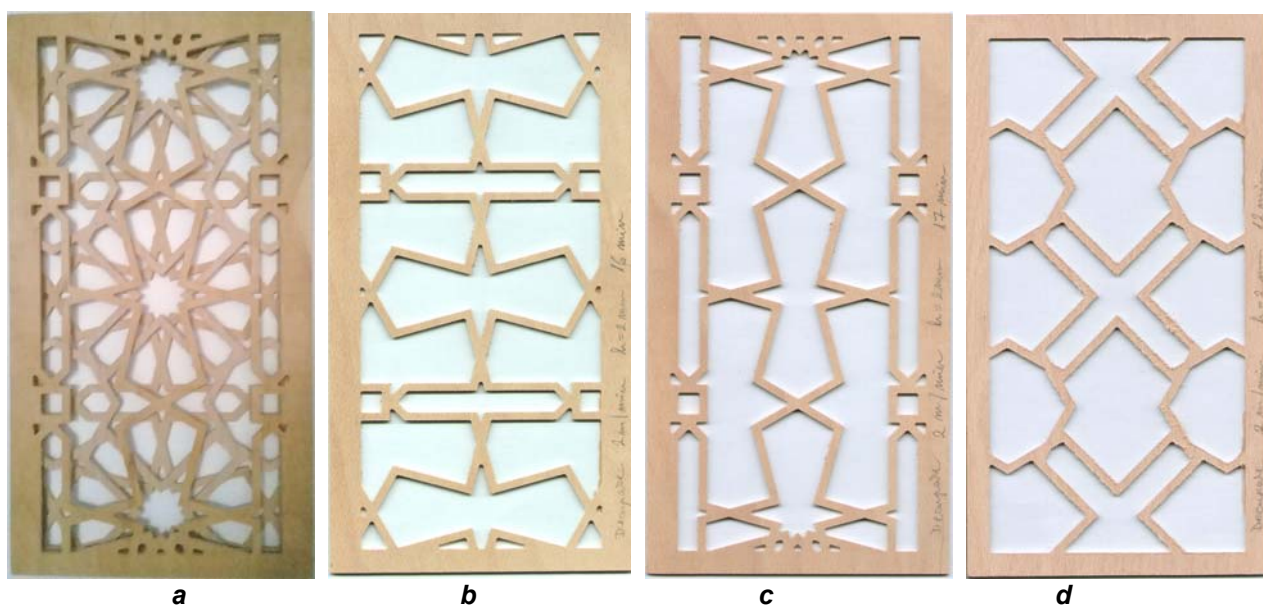


Fig.6.

**Fretted panels processed on CNC router from beech plywood.
a –combined model of part 1(b), part 2 (c) and part 3 (d).**

After the visual analysis of the beech wood panel, four details of each cut direction were marked in order to be investigated microscopically and measured. From these details, only those with more agglomeration of torn fibers were selected for this paper. Each microscopic image presented below is the detail of the marked zone on the adjoining panel image. In Figs 7- 13 there are presented the microscopic images taken from the beech wood panel.

Fig. 7b presents the measurements of the cut edges which are perpendicular to the wood grains.

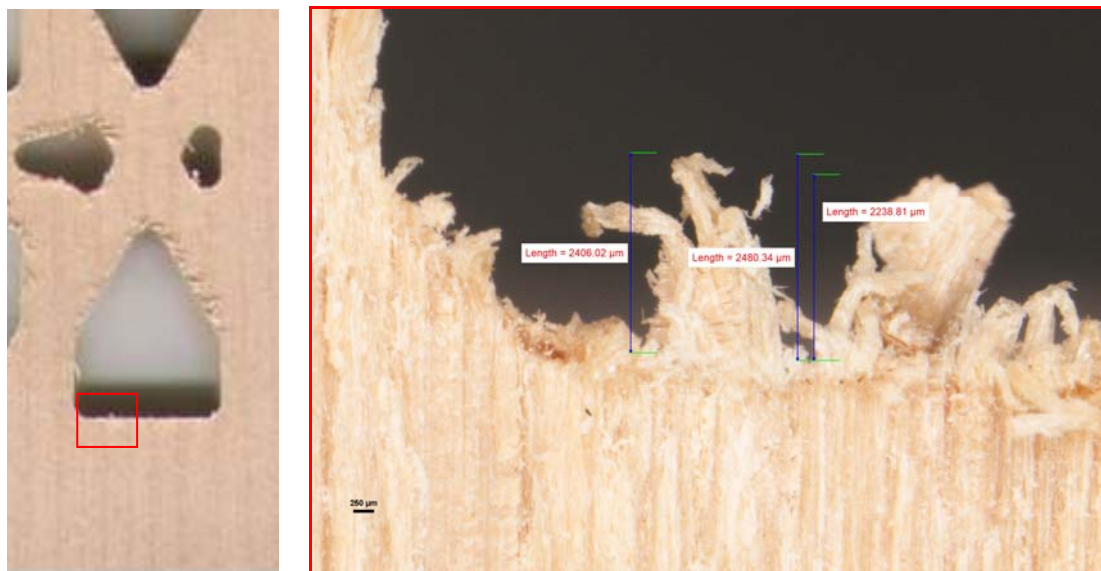


Fig.7.

Transversal cut edge (inclined at an angle of 90° relative to wood grains). Microscopic image (right) of the marked detail on the panel (left).

In Fig. 8, the longitudinal cut edge (inclined at an angle of 0° relative to wood grains) is presented at the microscopic level with measurements of the torn grains. Also, the position of this detail on the panel is marked in the image on the left side.

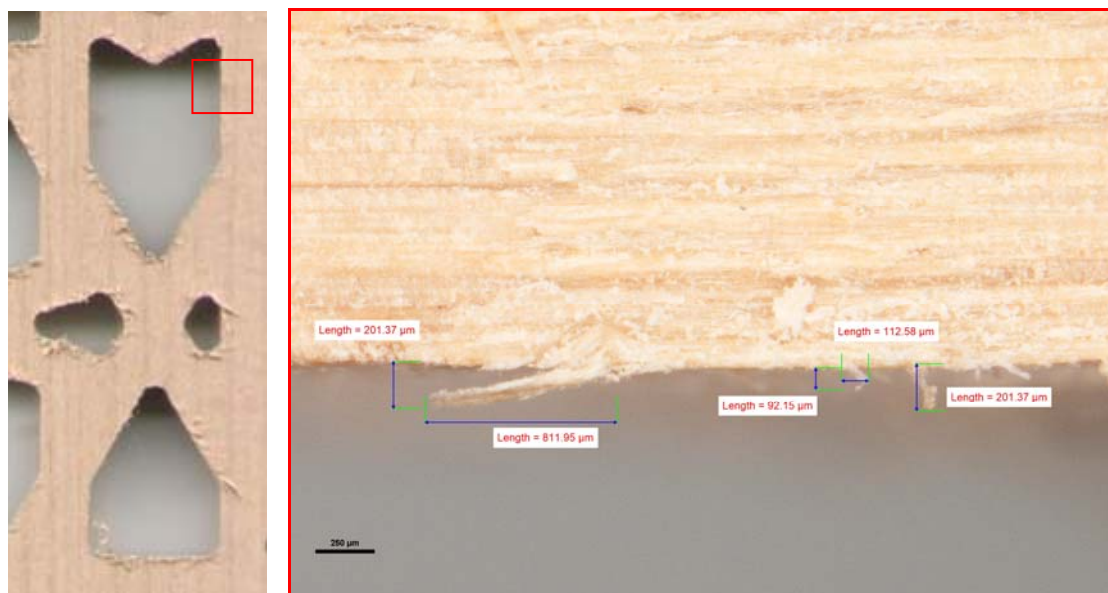


Fig.8.

Longitudinal cut edge (inclined at an angle of 0° relative to wood grains). Microscopic image rotated with 90° (right) of the marked detail on the panel (left).

In Fig. 9, the longitudinal cut edge (inclined at an angle of 0° relative to wood grains) is presented at the microscopic level with measurements of the torn grains. Also, the position of this detail on the panel is marked in the image on the left side. The same rule is valid for Figs 10-13, where the cut edges inclined with angles of 30°, 60° and 75° relative to wood grain direction are presented.

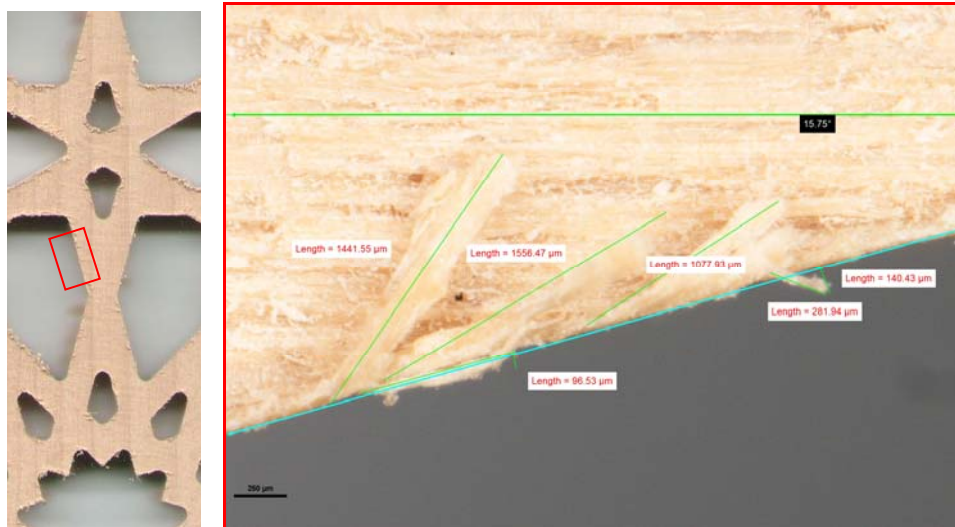


Fig.9.

Cut edge inclined at an angle of 15° relative to wood grains. Microscopic image rotated with 90° (right) of the marked detail on the panel (left).



Fig.10.

Cut edge inclined at an angle of 30° relative to wood grains. Microscopic image rotated with 90° (right) of the marked detail on the panel (left).

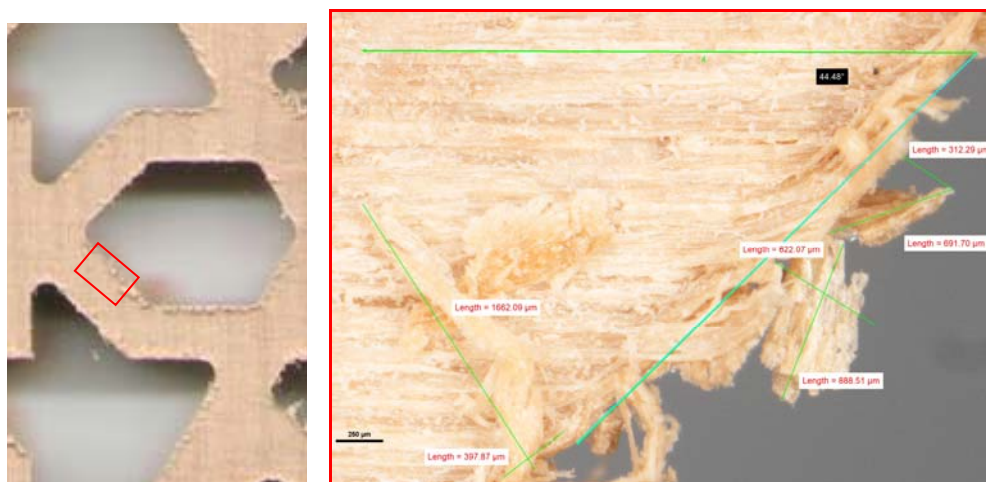


Fig.11.

Cut edge inclined at an angle of 45° relative to wood grains. Microscopic image rotated with 90° (right) of the marked detail on the panel (left).



Fig.12.

Cut edge inclined at an angle of 60° relative to wood grains. Microscopic image rotated with 90° (right) of the marked detail on the panel (left).

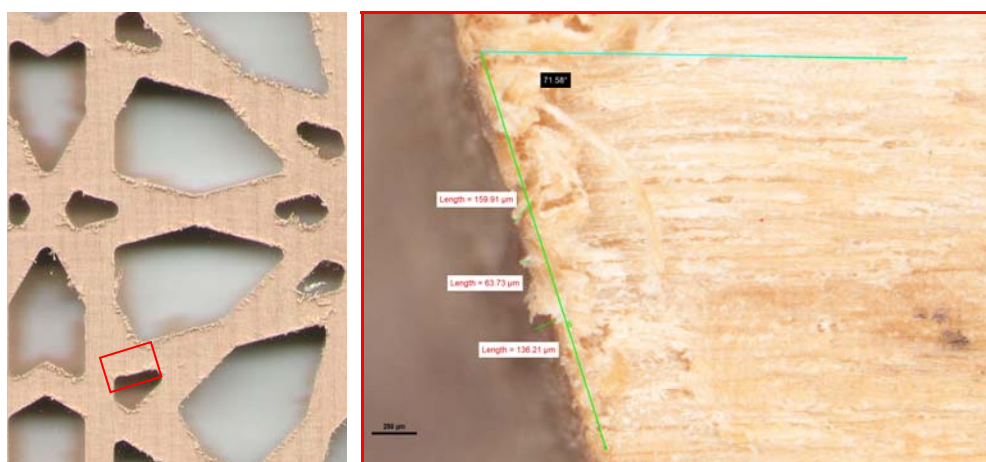


Fig.13.

Cut edge inclined at an angle of 72° relative to wood grains. Microscopic image rotated with 90° (right) of the marked detail on the panel (left).

In Figs 14 - 15 there are presented the microscopic images taken from the three plywood panels for the same inclination angles of the cut edges related to the wood grain direction as for the beech wood panel: 0°, 15°, 30°, 45°, 60°, 75° and 90°.

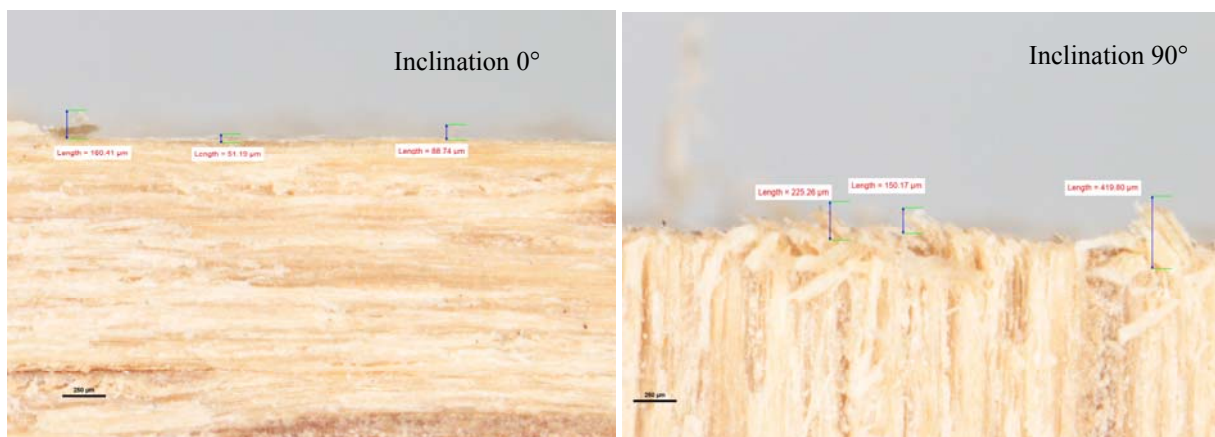


Fig.14.

Microscopic images for cut edge inclined at an angle of 0°(left) and 90°(right) relative to wood grains.

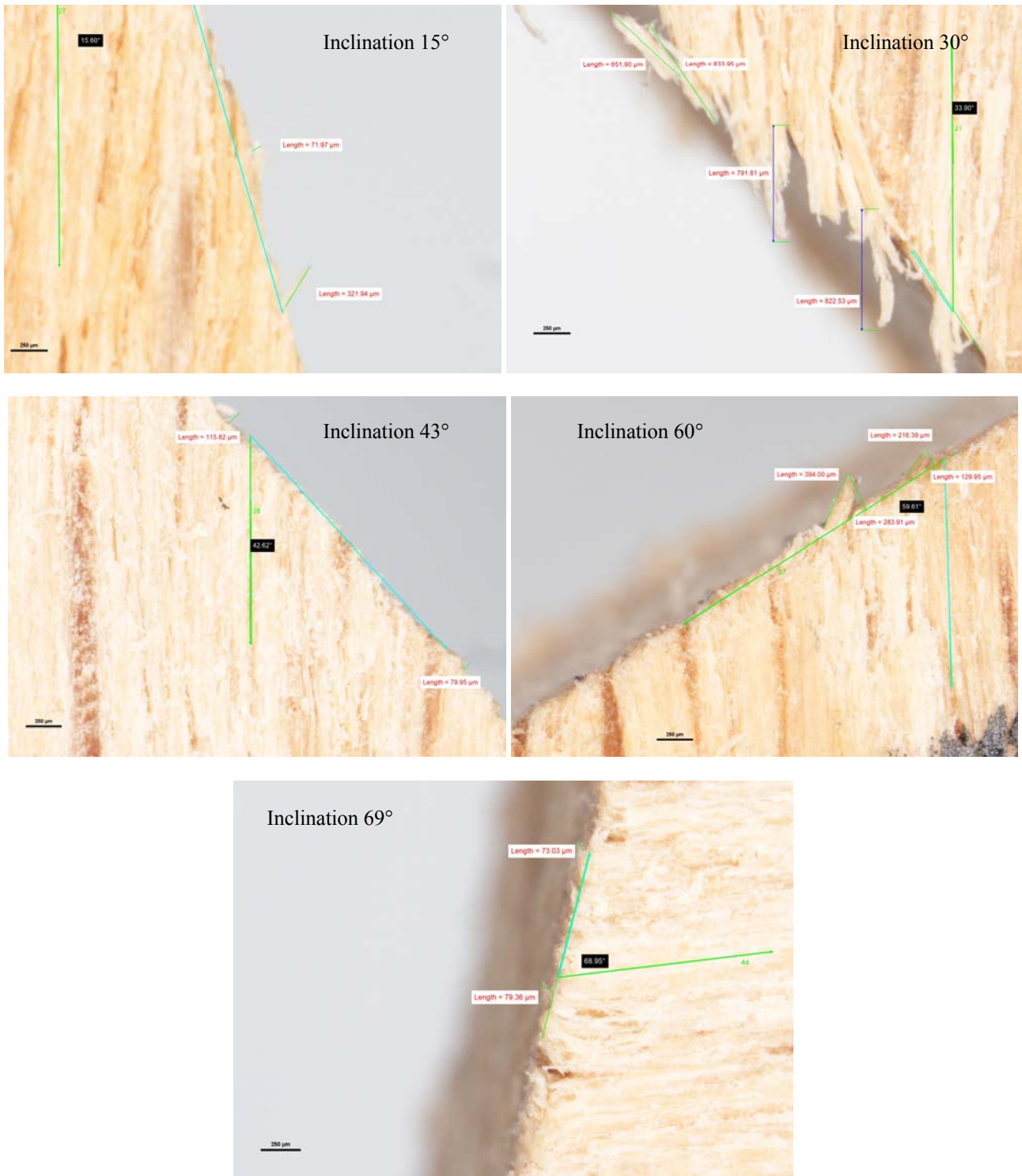


Fig.15.

Microscopic images for cut edge inclined at an angle of 0°(left) and 90°right) relative to wood grains.

Analyzing the images from Figs. 7-15, at a first glance, the cut edges of plywood looks cleaner that those of beech wood panel. In case of beech wood, the transversal cut edges are more ragged that those processed in plywood. The same situation is for cut edges inclined with angles around 45°, 15° and 75°. Instead, the cut edges of plywood are more ragged for an inclination angle of 30° related to the wood grain direction. The mean values of the recorded measurements and standard deviations are presented in Table 2 for all inclinations of cut edges and for both investigated materials. The mean values of the fibers heights, presented in Table 2, are calculated for 50 measurements on each inclination angle of the cut edges.

Table 2

Mean values of the torn fibers heights and standard deviations

No.	Material	Inclination angle of the cut edge relative to wood grain direction*						
		0°	15°	30°	45°	60°	75°	90°
	Plywood 4 mm	100 (55.3)	197 (176.8)	775.25 (84)	98 (25.4)	256 (111.5)	76 (4.2)	265 (139.4)
	Beech wood panel	387 (379.5)	766 (670.9)	208 (183.7)	762 (487)	213 (84.9)	120 (50)	1553 (847)

* Values in the parenthesis are standard deviation values

The data recorded in Table 2 shows the differences of the torn fibers heights for the two materials used in the experiment. Except the inclination angles of 30° and 60° of the cut edges relative to wood grain direction, for which the plywood recorded the highest sizes of the fibers, the rest ones belong to beech wood panel in terms of fibers sizes, especially for the transversal cutting direction. These results show that for the milling parameters used in the experiment, beech plywood of 4mm has a better quality of the cut edges than beech wood panel of 12mm.

If an evaluation of the productivity has to be considered as an important factor for the optimization of CNC milling process (Krimpenis et al. 2014), than the processing times presented in Table 3 may constitute a good indicator.

Table 3

Comparison between processing times

Panel type	Material	Processing time, in min
Part 1	Plywood 4 mm	16
Part 2	Plywood 4 mm	17
Part 3	Plywood 4 mm	12
Model	Beech wood panel	36

Calculating the total processing time when combining the three panels of plywood (part 1, part 2 and part 3) in order to obtain the whole model, than a value of 45min is obtained. Compared with the processing time of beech wood, the time is longer in this case. So, a final decision has to be taken as a compromise between quality of the processed surfaces and productivity. In the present research, where the experiment is conducted for an ornament, than an aesthetic evaluation has to be also considered.

CONCLUSIONS

In this paper a stereo-microscopy analysis was conducted to evaluate the quality of the edges obtained by CNC milling of fretted panels with geometric pattern. For this purpose, a beech wood panel of 12mm thick and 3 panels of 4mm beech plywood that forms the model by their combination have been selected. After CNC milling the panels according to the geometric patterns, the measurements of the torn fibers heights have shown that the quality of the edges in case of plywood is better than for the beech wood panel. The more disadvantageous processing direction of beech wood panel is the transversal one, whilst for the plywood is the one inclined with 30° in relation to wood grain direction. The cut edges of beech wood panel are in general more ragged than those of the plywood panels. Instead, the processing time for beech wood panel is shorter than for the three plywood parts of the model. The decision of choosing the right material is a compromise between the quality and productivity on one hand, and the aesthetic value of the ornament, on the other hand. The combination of the three plywood panels looks interesting and may tip the balance to this choice.

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