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Analysing surface geometry of selected hardwood species at different humidity levels

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ABSTRACT

Wood is a natural material continuously changing its moisture content according to the environment's humidity. Due to the moisture variation of the environment, wood samples change their dimensions also, as they shrink and swell. The effect of water vapour exercited on the surface of wood samples differs also, according to the anatomical and machining specificities of the surface, whether it is a tangential or a radial section (E. Magoss, 2008).

In this study different wood species were used, beech (*Fagus*), poplar (*Populus*), elder (*Sambucus*), and maple (*Acer*) with radial and tangential face, in order to study their roughness at different humidity levels. After sample preparation (Benkreif et al 2021), specimens were put in climate chamber at a temperature of 20 °C and relative humidity of 90 % and taken out for measurement at moisture content values close to 6 %, 8%, 10 %, 12 %, 14 %, 16%, 18% and 30 %. At each relevant MC surface roughness measurement was performed, were Rq and Rz parameters were recorded (EN ISO 4288). The results indicated that relation between moisture content and surface roughness can be given as a polynomial function in case of all the studied hardwood species.

INTRODUCTION

In case of a machined wood sample, the wood surface is the interface between the wood cells and the environment. Wood is a natural material continuously changing its moisture content according to the variation of the humidity of the environment. The continuous moisture transport affects the parameters of wood surface (Lagaňa at al. 2021). Surface roughness is one of the interfacial parameters which is supposed to vary with the variation of the moisture content of the wood (Papp and Csiha 2017, gurau and Csiha 2015).

Surface roughness of solid wood can be influenced by many influencing factors like annual ring variation, wood density, cell structure early wood and latewood ratio. In the case of porous species, such as oak and black locust (Benkreif at al. 2020), surface quality of the solid wood surface is important since it is necessary to apply filler or other refinishing coating to make the surface more smooth. However its will result an increase in production cost. Soft and non-porous species or species with distinctive coloured hardwood will not create such problem but they will needs extra sanding process for more uniform surface (Zhong at.al 2013).

Maple is a medium to hard wood with light colour. Its advantages relay on its shock resistance with a fine texture and an even grain. It has as well high durability, can be easily stained and is more stable than many other species because of its fine and straight grain structure (Zhong at.al 2013).

Beech is a heavy, pale coloured medium to hard wood. Its rays are fine, tight and large, which making it similar in appearance to maple. It has a high shock resistance and takes stains well. Even if it is a hard and strong material, it does not have the endurance level in comparison to other hardwoods (Zhong at.al 2013).

Poplar is one of the most used wood species in wood based composites. The utilization of poplar wood is restricted due to its low-density and dimensional instability. Many effort have been made that aimed to enhancing performances of poplar by densification to rise the density and the mechanical strengths of the final wood product (Bao et al. 2016, Brahmia at al. 2020).

EXPERIMENTAL METHODS

For this study different hard wood species were used: beech (*Fagus*), poplar (*Populus*), elder (*Sambucus*), and maple (*Acer*) with radial and tangential cut. Surface was sanded with sanding belt of 120 grit size and samples were cut to dimension of 70 mm x 50 mm x 15 mm. After samples preparation, specimens were put in climate chamber for temperature of 20 °C and relative humidity of 90 % until reached 6 %, 8%, 10 %, 12 %, 14 %, 16 %, 18 % and 30 % MC. On every sample 10 surface roughness measurements were performed, for each combination, using MAHR S2 Perthometer according to standard EN ISO 21920-3: 2022, and the following parameter were recorded: Rq, Rz.
Using the surface texture parameters set in EN ISO 21920-2:2022 the surface roughness of different surfaces can be characterized and evaluated in comparative way. For the scope of the research two parameters were selected from the ones specified by the standard: Rq and Rz. The root mean square roughness of a surface Rq (RMS) is the root mean square average of the roughness profile ordinates, whilst the mean roughness depth Rz is the arithmetic mean value of the single roughness depths Rzi of 5 consecutive sampling lengths. A single roughness depth Rzi is the vertical distance between the highest peak and the deepest valley within a sampling length.

RESULTS AND DISCUSSION

After measuring both the surface roughness and the MC of the samples, the results were studied and represented in the figures below (Fig.1-4).
It can be stated that an increase of moisture content of samples results in an increase of the surface roughness (expressed by Rq and Rz) (Table 1).

Table 1: Rz(µm) and Rq(µm)of beech, poplar, maple and elder for MC (6-30 %)

MC (%)			6	8	10	12	14	16	18	30
Beech	T	Rq(µm)	4.66	4.91	5.45	5.51	5.53	6.43	7.46	15.77
		Rz(µm)	28.75	31.01	34.06	34.87	36.23	40.37	43.92	78.61
	R	Rq(µm)	4.87	5.51	5.6	7.45	7.62	7.81	7.93	13.35
		Rz(µm)	29.1	32.05	35.18	42.02	44.17	46.36	44.81	69.97
Poplar	T	Rq(µm)	6.51	6.65	8.22	9.01	9.46	10.37	17.08	22.27
		Rz(µm)	40.06	41.59	49.69	55.45	55.32	62.02	91.47	111.19
	R	Rq(µm)	7.97	8.2	10.32	10.59	11.39	12.19	13.71	19.24
		Rz(µm)	45.103	46.68	58.14	63.51	65.72	67.81	70.4	93.44
Maple	T	Rq(µm)	4.77	5.33	5.45	5.67	5.69	5.7	6.03	9.87
		Rz(µm)	28.26	32.18	35.64	32.77	34.75	33.82	35.81	59.36
	R	Rq(µm)	4.84	4.91	4.93	5.2	6.05	6.24	6.86	12.52
		Rz(µm)	28.71	29.77	29.65	31.41	35.11	4.73	40.2	67.18
Elder	T	Rq(µm)	5.18	4.67	5.08	5.86	7.95	7.96	6.63	10.04
		Rz(µm)	32.03	30.26	31.54	36.44	48.06	49.54	41.02	57.37
	R	Rq(µm)	5.8	4.86	5.43	7.55	6.63	7.61	7.41	11.87
		Rz(µm)	37.39	30.39	35.01	44.99	40.34	46.15	51.87	84.82

Note: R: Radial cut, T: Tangential cut.

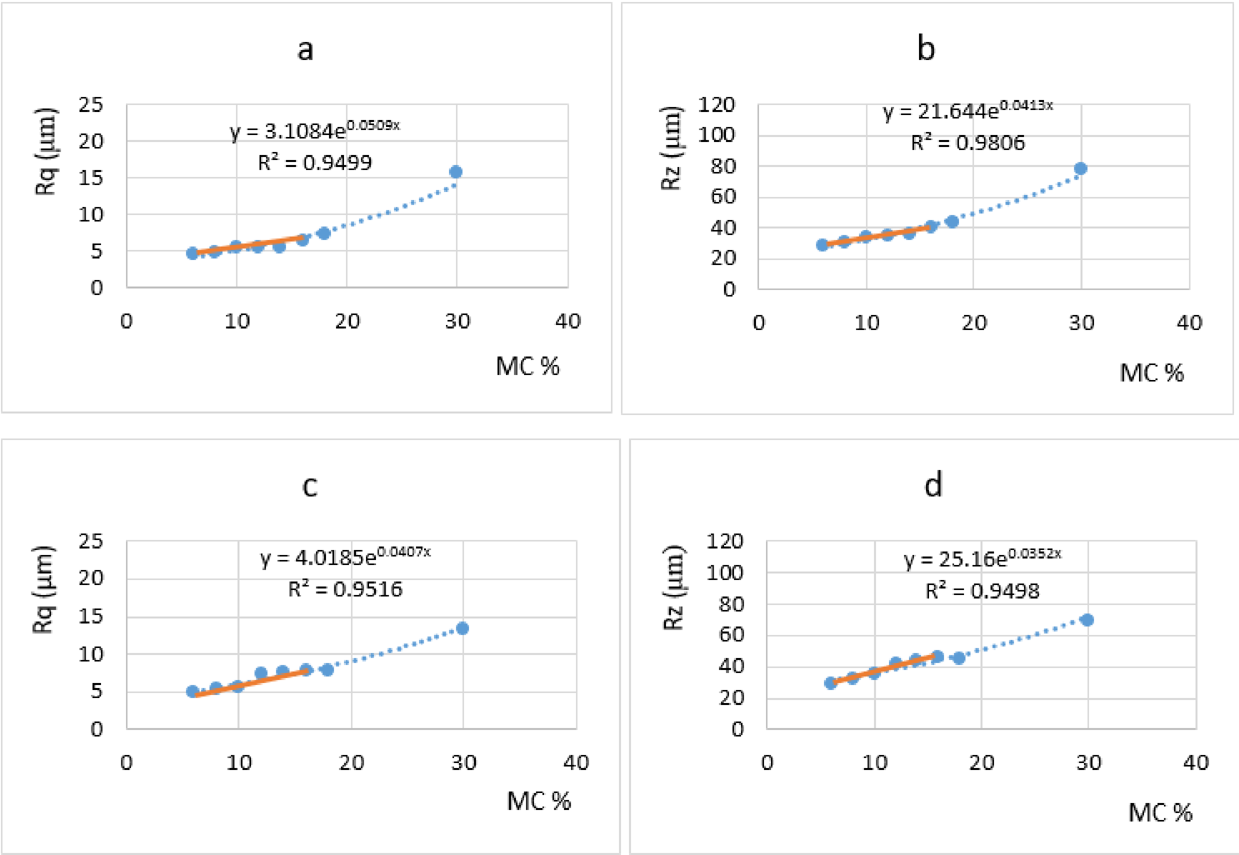

Figure 1: a) Rq tangential cut for beech. B) Rz tangential cut for beech. c) Rq radial cut for beech. d) Rz radial cut for beech

The surface roughness of the **beech** samples shows similarities on the tangential and radial surfaces for RMS parameter, due to the increase in the moisture content.

Considering the mean roughness depth Rz of tangential and radial beech surfaces, the trend is similar, but roughness of the tangential surfaces is somewhat higher. This matches with the general expectation, that usually tangential surfaces are more sensitive to the variation of moisture, due to the larger portions of early wood.

In case of beech the trend of the Rq and Rz parameters on tangential and radial surfaces is rather of identical trend, leading to the conclusion that the two parameters reflect with the same effectiveness the roughness of the surface.

The RMS parameter of tangential and radial surfaces of **poplar** samples shows similarity up till 16% MC, but at elevated levels of moisture content, the tangential surfaces are more sensitive than the radial ones.

The similar response to MC variation on tangential and radial surfaces is valid in the lower regions of MC ranging from 6% to 16% MC. Accidentally this region coincides with the moisture content values relevant for the daily practice of wood processing.

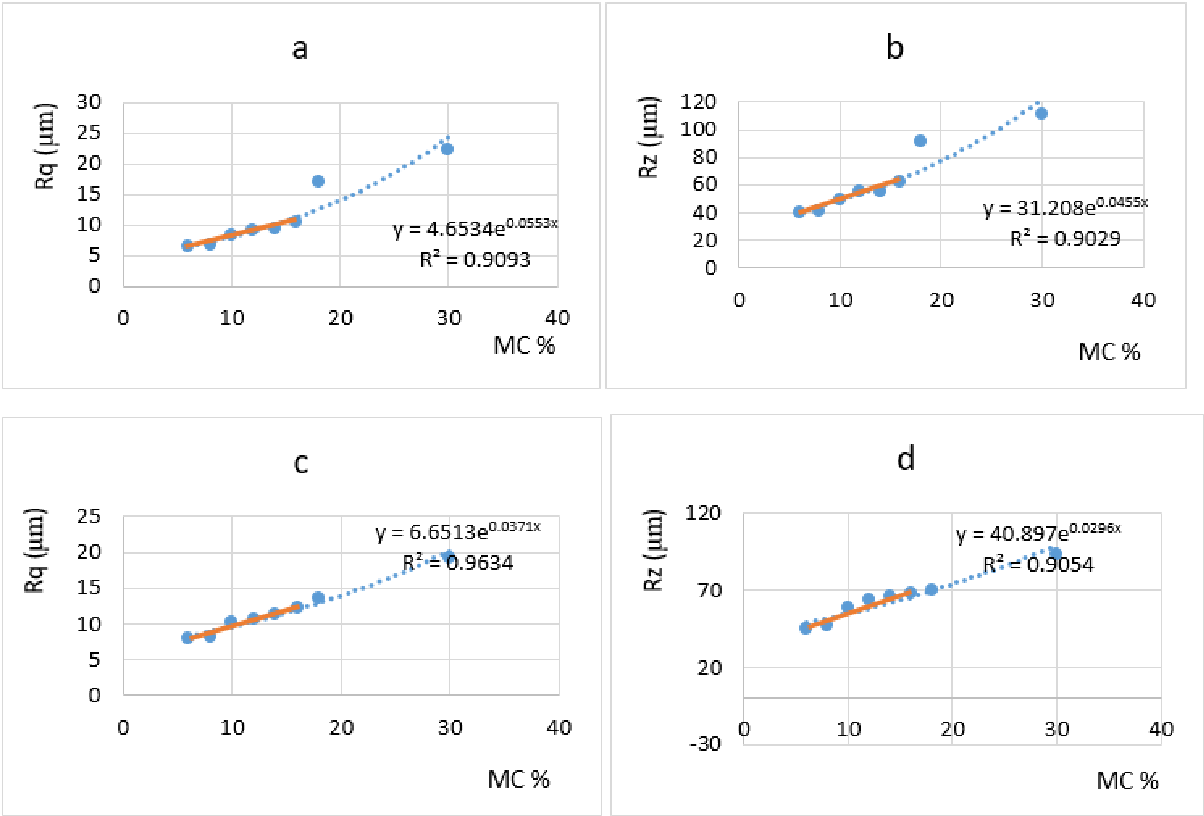

Figure 2: a) Rq tangential cut for poplar. B) Rz tangential cut for poplar. c) Rq radial cut for poplar. d) Rz radial cut for poplar

The trend of increase of roughness due to MC variation expressed by the Rz mean roughness depth on tangential and radial poplar surfaces shows similarity up till 16% MC, but at elevated levels of moisture content, the tangential surfaces are more sensitive than the radial ones. The similar response to MC variation on tangential and radial surfaces is valid in the lower regions of MC ranging from 6% to 16% MC.

In case of poplar the trend of the Rq and Rz parameters on tangential and radial surfaces is rather of identical trend, leading to the conclusion that the two parameters reflect with the same effectiveness the roughness of the surface.

Compared the behaviour of poplar and beech samples it can be assumed, that up till 16% MC both wood species show only a limited roughening reaction to increasing moisture, but above this poplar brakes out and shows an intense increase of its roughness, somewhat less than the double of the beech.

It can be stated that the roughening response to MC variation of the tested different wood species is wood species dependent.

In case of **maple** samples, the roughening of tangential and radial surfaces has mostly the same trend both for RMS and Rz surface roughness parameters. The similar behaviour of tangential and radial surfaces during swelling lead to the conclusion that the anatomic structure of maple latewood and early wood is rather uniform. Based on this finding, maple can be suggested for scientific research as etalon wood species, due to a preferable uniform anatomic structure its behaviour on tangential and radial surfaces is similar. Up to 16% moisture content, the reaction of maple surfaces to increasing moisture content is negligible. Starting with 18% maple starts to roughen and doubles its original roughness in the region of 30% MC. As previously stated, the 6% to 16% wood moisture content is the region relevant for the industrial practice.

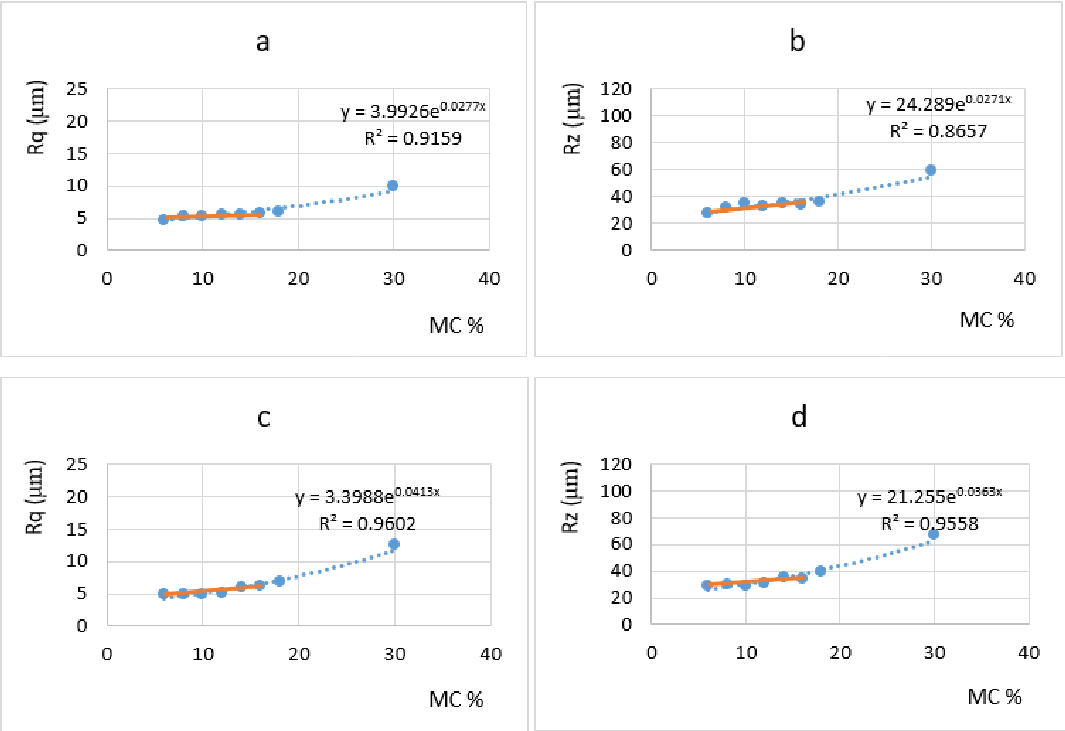

Figure 3: a) Rq tangential cut for Maple. B) Rz tangential cut for Maple. c) Rq radial cut for Maple. d) Rz radial cut for Maple

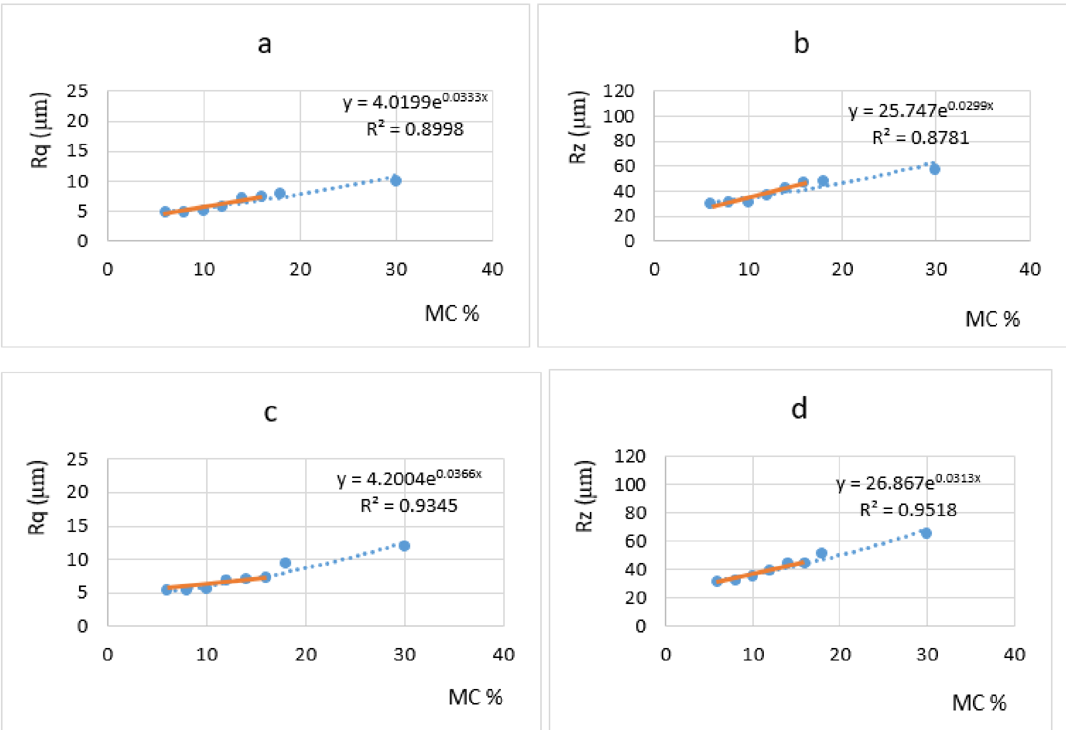

Figure 4: a) Rq tangential cut for alder. B) Rz tangential cut for alder. c) Rq radial cut foraelder. d) Rz radial cut for alder

Most wetting and adhesion processes need to be performed in this moisture content domain. Alder samples during the moistening process show similar roughening trends on both tangential and radial surfaces. The increase in the surface roughness expressed by RMS and Rz parameters is similar on both surfaces, radial surfaces seem to be somewhat sensitive to MC variation. Up to 16% moisture content the reaction of alder surfaces to increasing moisture content is negligible. As previously stated, the 6% to 16% wood moisture content is the region relevant for the industrial practice. In this moisture content region roughness of alder surfaces showed to be stable. Starting with 18% MC maple starts to roughen and doubles its original roughness in the region of 30% MC.

CONCLUSIONS

It can be stated that an increase of moisture content of samples results in an increase of the surface roughness (expressed by Rq and Rz).
It can be stated that the roughening response to MC variation of the tested different wood species is wood species dependent.
The test results support that earlier assumption that usually tangential wood surfaces are more sensitive to the variation of moisture, due to the larger portions of early wood, than the radial surfaces, except in case of maple, alder and beech. The surface roughness of maple, alder and beech was found to be very stable to the moistening process, with no significant difference between the tangential and radial surfaces. For these wood species, the linear portion of the exponential equation is mostly horizontal, showing a stability of these wood species towards moistening, up to 16%.
The trend of roughening in case of the studied wood species follows exponential equation, but in the lower MC regions (from 6% to 16%), otherwise typical to the industrial practice, - a linear equation can be fit, both for RMS and Rz parameters. All wood species show a break out in roughness from 18% MC.

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