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CNC WOOD MACHINES ACCURACY AND REPEATABILITY

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ABSTRACT

Machine accuracy can be defined as a degree of coincidence between measured, calculated or specified, and supposedly correct, already known or given physical size value. Repeatability is a machine capability to achieve predetermined physical size value in numerous repetitions, at the same working conditions.

There are many factors which affect wood machine accuracy and repeatability, and consequently, the final product quality. Determining these factors and finding out their values is difficult and expensive. The main goal of this paper is to establish a possibility for implementation of a new, reliable enough method for product dimension and shape control, using the photography and suitable software (Digimizer for dimension and Meshroom for shape determination), in order to obtain satisfying results for wood processing. Namely, accuracy and repeatability must fit into given tolerances used for wood products, which are significantly less demanding than those in metal works.

Applying this particular measuring method, CNC wood machine users would be able to control working parameters on a regular basis, improving the product quality.

Key words: CNC, accuracy, repeatability

1. INTRODUCTION

Modern wood machining technologies are increasingly used in the countries of Western Balkans aiming at achieving better productivity, production quality and, last but not least, minimizing the lack of work labor. CNC machines are highly productive and flexible as well. However, many enterprises choose used machines with expired or almost expired technological life cycle. Those machines often give inadequate production accuracy, consequently raising the amount of rejects, amount of material, energy and production time, as well as the total costs. Calibration of these machines is mostly time-consuming, expensive in terms of human labor and equipment needed. In the light of the previously said, the idea of the possibility to perform a simple machine accuracy measurement emerged. The basic idea was introduction of photography and software analysis in order to determine the possibility of avoiding machine measurement inaccuracies.

2. MACHINE ACCURACY AND REPEATABILITY

Machine accuracy can be defined as a degree of coincidence between measured, calculated or specified, and supposedly correct, already known or given physical size value, and also the maximum translational or rotational error between any two points in the machine's work volume (Slocum A. 1992). A Machine is supposed to produce parts of a required shape and dimensions keeping the required tolerances, and to achieve the desired surface roughness. CNC machines accuracy is greater compared to the conventional machines, so the former demand more precise and more sophisticated methods for working parameter evaluation.

Repeatability presents a machine capability to achieve predetermined physical size value in numerous repetitions at the same working conditions. In other words, it is the error between a number of successive attempts to move the machine to the same position. Repeatability is often considered to be the most important parameter of a computer controlled machine (or sensor) [Slocum A. 1992].

Stepper motor used on CNC machines and ball screw pitch will ensure accuracy. Stepper motor of 1.8 degree per step means 200 steps per revolution. Ball screw of 5 mm per revolution, divided by 200 means 0.025 mm.

Accuracy and repeatability must fit into given tolerances used for wood products, which are significantly less demanding than those in metal works.

Furniture elements are often made in batches, sometimes containing hundreds of pieces. For industrial production, it is important that the parts produced are interchangeable during assembly. This means that from the series, from a large number of pieces, each of them can be fitted in the product without any previous pairing or finishing. Reciprocal interchangeability is a feature of the parts of the product enabling them to be interconnected without prior adjustments and refinements, at the same time ensuring the conditioned quality and functionality of the product. However, due to the imperfection of machines, tools and errors of the worker, as well as due to the material properties, the production of the final wood products must take into account that the dimensions and shapes of the machined parts will deviate to some extent from the nominal measures and the desired shapes.

The widely used type of joint for conecting furniture is the hole used to join the dowel/hole. Holes can be made on conventional or CNC machines. The errors that occur in this process are numerous and directly affect the quality of the product. A very common problem encountered by furniture constructors is the type of fit and the tolerance class. The hole deformation and the deformation of the dowel result in a small contact surface. In order to achieve adequate rigidity and durability of the product, the constructors are forced to increase the number of dowels above the required number. Increasing the number of dowels results in longer assembly times, which directly affects longer operating times. The deformation occurs in cases of combination of a machine with low accuracy and poorly prepared tools, while deformation of the dowel is most often caused by inadequate moisture content, so that after drying a dowel cross section deviates from the "ideal" circle. As a sum of these two errors, the result is point contact instead of surfaces contact between the dowel and the holes.

When making holes on numerical machines, those two problems are easier to counteract, and the steps taken will depend on the shape of the tool and the processing parameters. The widely used standard for tolerating measures in the furniture industry is DIN68100. For tolerating joints, it is recommended to use acuracy class TD10 and TD15. The size of the overlap should range from 0.1 to 0.2mm, (Džinčić and Palija 2017), (Džinčić et all 2017), (Džinčić, Živanić 2014). If we compare the accuracy of the stepper motor with the prescribed tolerances, we will see that the accuracy of the stepper motor is by 4 to 10 times as high as the required tolerance.

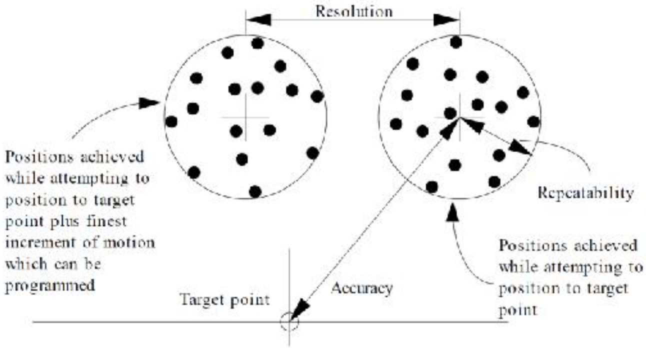

Figure 1. *Machine accuracy and repeatability (Slocum A. 1992)*

The third parameter is resolution, but it depends on the machine construction, and it can be defined as the smallest mechanical step the machine can make during point to point motion, and it gives a lower bound on the repeatability (Slocum A. 1992).

Machine accuracy and repeatability depend on many factors. Main factors that influence them are presented in Figure 2 (Laspas T. 2014).

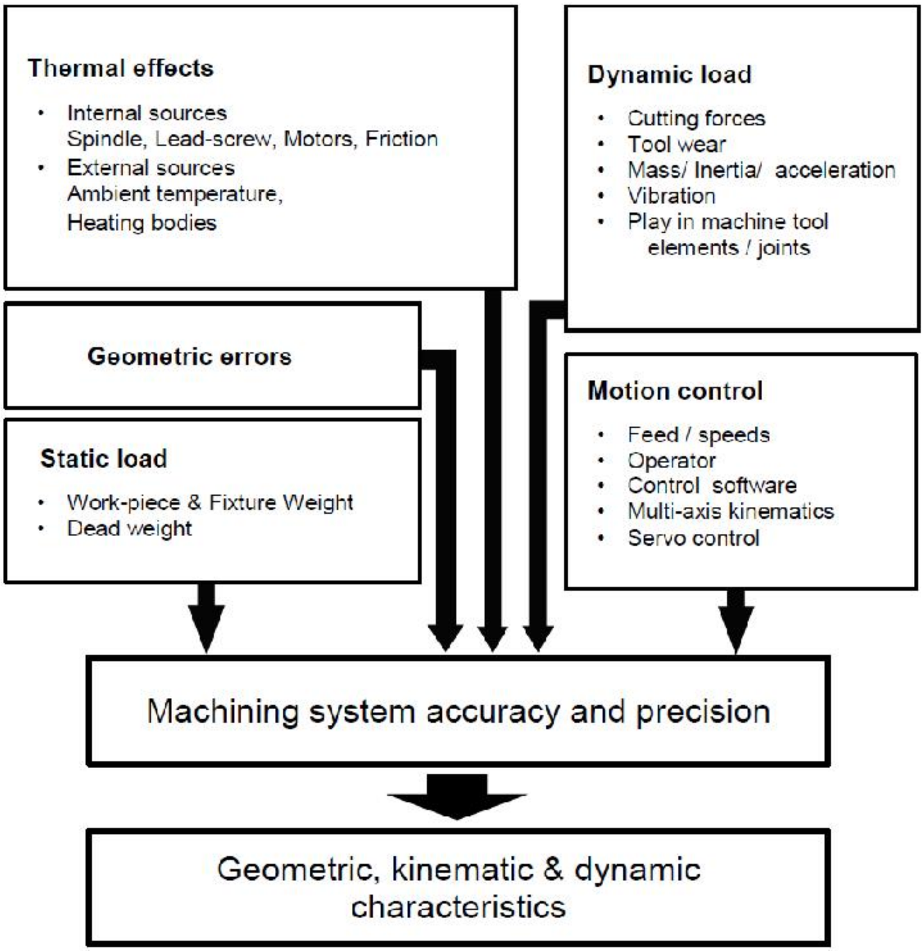

Figure 2. *Main factors that affect machine accuracy (Laspas T. 2014)*

Modern CNC machines usually have real-time monitoring technology, failure analysis and troubleshooting methods.

CNC machine commonly used following methods of diagnosis: direct method, CNC system self diagnostics, functional program testing method, Module exchange, the principle of analysis, PLC procedural law (Kuric I. et al, 2012).

3. MEASURING ACCUARCY AND REPEATABILITY

The main goal of this paper is to establish a possibility for implementation of a new, reliable enough method for product dimension and shape control using the photography and suitable software (Digimizer for dimension and Meshroom for shape determination), in order to obtain satisfying results for wood processing.

Applying this particular measuring method, CNC wood machine users would be able to control working parameters on a regular basis, improving the product quality.

Dimensions measurements from the photos enable analysis of the CNC machines for boards (predominantly 3-axe machines). In the previous case, bulk accuracy is not important since the tool motion is linear.

The tryout of implementation of this method was performed on side boards of wardrobe, with height of about 2000 mm, width of 600 mm and thickness of 18 mm. Drills and cuts were performed on BIESSE SKIPPER 100 machine equipped with displacement (move) control system (Figure 3).

The photos were taken with Nikon D90 camera, with Nikkor 50 mm f 1.8 objective, as shown in Figure 4.

Figure 3. *Biesse Skipper 100*

Figure 4. *Positioning of camera*

The distance between the camera and the working piece was 4 m, ensuring the entire board is in the scope. All boards were marked and positioned along the ruler. The role of the ruler was to define the true dimensions on the photo. After photographing, all the photos were analyzed using the Digimizer software. All the photos were rotated for 180 degrees in order to set the reference point in the upper left corner.

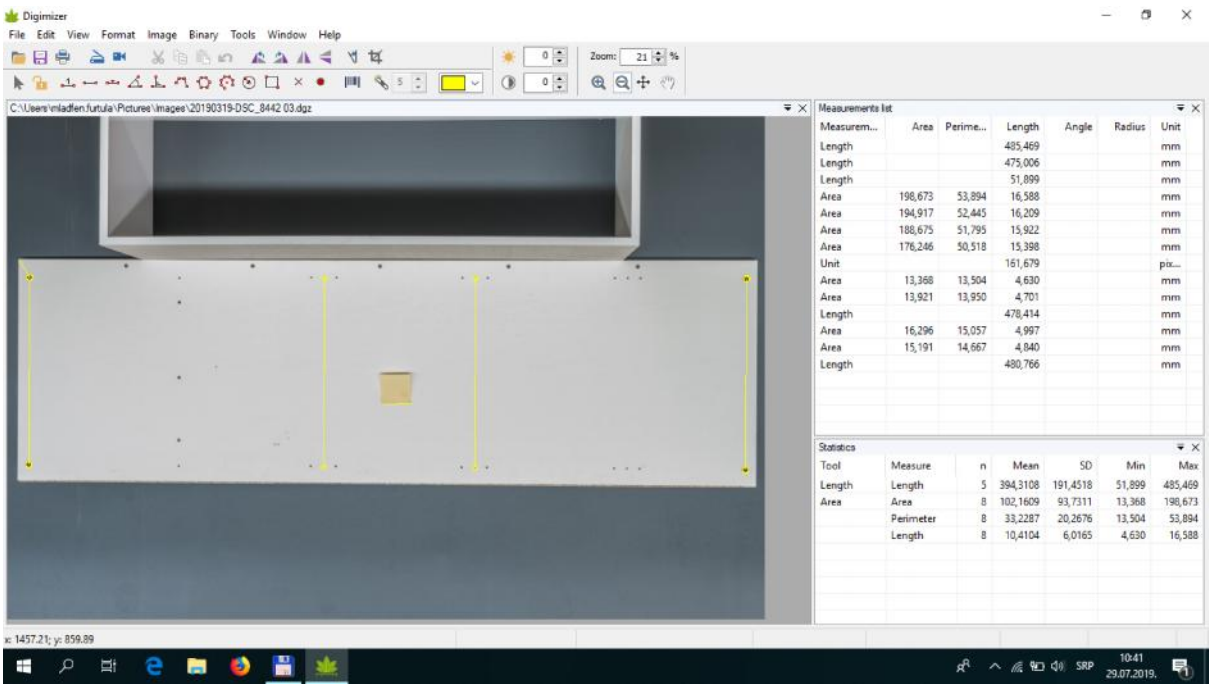

Figure 5. *Analyzed picture in Digimizer*

All boards were measured in the Digimizer software by measuring the distance between the reference point and characteristic holes in the board corners. Along with this, the control measurements were performed in tpsDig 232 software, for the same distances.

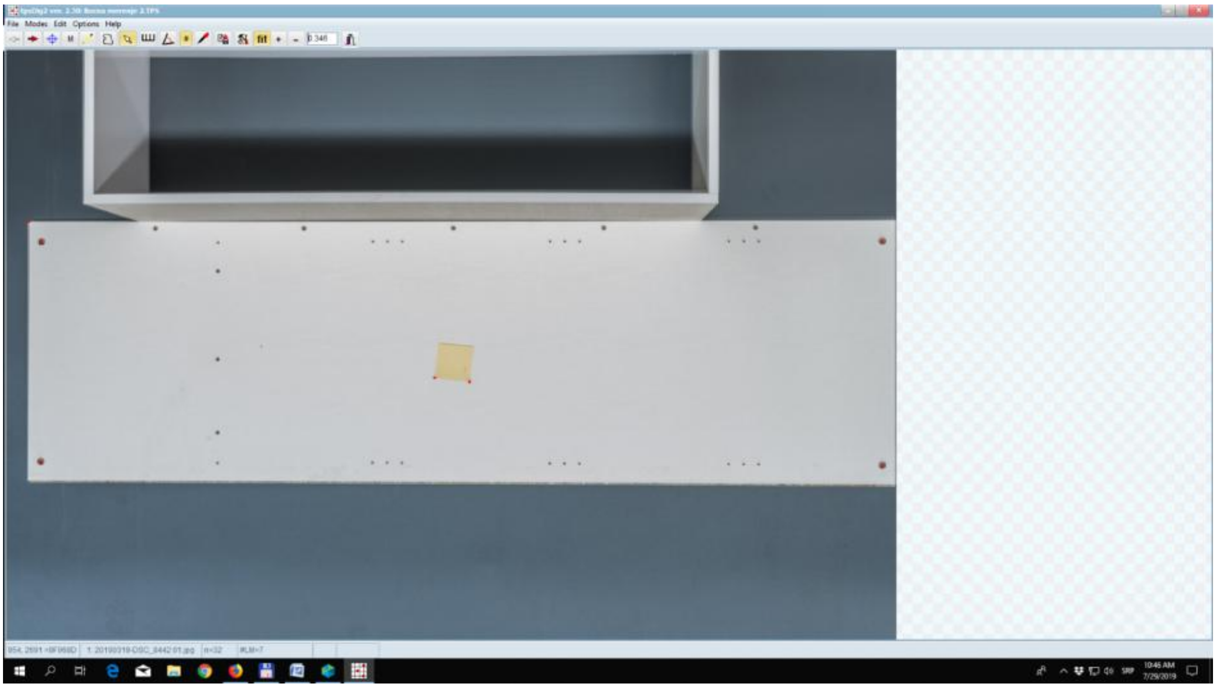

Figure 6. *Measuring with tpsDig232*

This series of measurements failed since the distance of the camera was too big. Namely, the camera resolution of 12 mega pixels is basically 0,5 mm per pixel at the chosen distance. The objective applied did not distort picture, so it is not wide ranged.

The shape control method is required for machines that operate with more than just 3 axes (more than 3 degrees of freedom). Acquiring 3D model is possible by applying 3D scanners, but unfortunately these are fairly expensive, especially for high precision scanners (0,1 – 0,2 mm). This is the reason why the model making was done by photogrammetry, i.e. by taking shoots from as many angles as possible and putting them all together in a 3D model. There are many programs for this purpose. There are commercially available programs, as well as those which are freeware. Such commercial programs are: iWitness PRO, Pix 4D, Photo Modeler, Autodesk ReCap, Reality Capture, Metashape, whereas freeware ones are: COLMAP, Regard 3D, Visual SFM, Open MNG and Meshroom.

The object was photographed by a mobile phone camera (Nokia 6, 16 mega pixels, f 2.0, 1µm, PDAF) from as many angles as possible. Afterwards those photos were fed as input data into the proper software.

Figure 7. *3D object*

The program applied was Meshroom 2019. 1.0, as well as Photo Modeler Premium (later used in Evaluation mode). Meshroom software did not fulfill the expectations since it failed to produce a 3D model (the main cause is the inappropriate computer equipment – too slow graphic cards and lack of RAM memory).

On the other hand, Photo Modeler Premium managed to produce a 3D model, but for the further analysis additional equipment was needed, mainly camera adjustments, as it worked in uncalibrated camera mode.

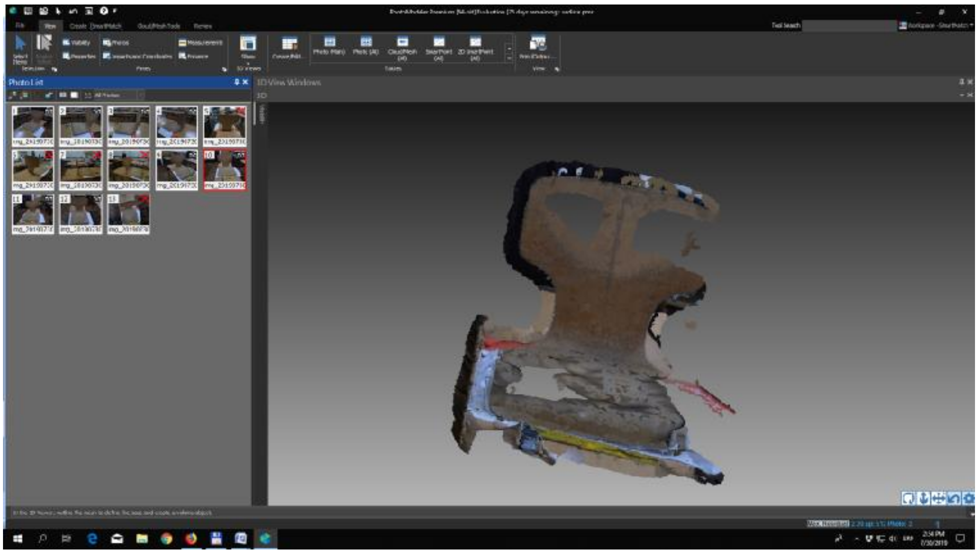

Figure 8. *Working with Photo Modeler Premium*

4. CONCLUSION

Possible procedures for determination of accuracy, precision and repeatability applying photos and photo software analysis were presented in this paper. Although the initial experiments didn't perform in the expected manner, such type of approach has sufficient potential for supposed applications.

It is also to be mentioned that much better results would be obtained with better computer and photo equipment, and that such measurements could be ideal for fast control measurements at Universities for practical educational purposes and commercial service for CNC machine owners for calibrating accuracy and repeatability of their machines.

Future work in this area will demand precise experimental setup in terms of proper geometry and positioning of the camera, possible signal generating, in order to compare it with those from machine transducers, and finally developing two channel control loop system.

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