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COMPARISON OF TECHNICAL AND ECONOMIC PARAMETERS OF DRILLING OF WOOD BASED PANELS WITH CNC AND TRADITIONAL WOODWORKING MACHINES

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Abstract

The technology of final wood processing has undergone during the last two decades positive changes, achieving a rapid development through the application of advanced technologies as the numeric-controlled machines (CNC). The focus of this paper lies in the comparison of technical and economic parameters in drilling operations, with a three-dimensional CNC mill-drill machine and with a traditional, horizontal-vertical tenoner drilling machine. The materials used in the study are particleboard panels for the production of a window-case. The study compares (i) the cutting time of the constructive parts of the window-case measured by the software of the CNC machine, and through a chronometer at the tenoner drilling machine and (ii) the cost of labor force engaged. The comparison of technical and economic parameters measured/calculated reveals clear advantages of the three-dimensional CNC machine over the traditional one. These advantages consist in operations time savings, higher quality of processing, lower internal transportation times, lower costs of processed parts and automatic optimization of material.

Keywords: Technology, tridimensional CNC machines, drilling, solid wood panels, parameters.

Özet

Odunun son ürün olarak işlenme süreci teknolojisi son yirmi yılda sayısal olarak kontrol edilebilen cihazlar olarak adlandırılan ve kısaca CNC olarak bilinen cihazların üretilmesiyle hız kazanmış ve olumlu yönde katkılar sağlamıştır. Bu çalışmada delme işlemlerinde kullanılan üç boyutlu CNC dişli delici makinesiyle geleneksel, yatay-dikey tenoner delme makinesinin teknik ve ekonomik yönlerden karşılaştırması ele alınmıştır. Çalışmada kullanılan malzeme pencere pervazlarının yapımında kullanılan sunta levhalardan oluşmaktadır. Çalışma (i) CNC yazılımının zaman ölçeri ve tenoner cihazında kronometre ile pencere pervazlarının yapımında kullanılan sunta levhaların kesilme sürelerinin ölçümünün ve (ii) gerekli iş gücü maliyetlerinin karşılaştırılmasını kapsamaktadır. Ölçümler ve yapılan karşılaştırmalar sonucunda teknik ve ekonomik parametreler bakımından CNC cihazının geleneksel cihaza nazaran kayda değer avantajlar sağladığı tespit edilmiştir. CNC cihazının; işlem süresinin kısa olması, yapılan işin niteliğinin iyi olması, düşük atölye içi taşıma zamanı, parça başına daha düşük işleme maliyeti ve malzemenin otomatik olarak iyileştirilmesi bakımından daha avantajlı olduğu tespit edilmiştir.

Anahtar kelimeler: Teknoloji, Üç boyutlu CNC cihazları, Delme, Sağlam ahşap paneller, Parametreler.

INTRODUCTION

Producers, not only in the wood processing industry, shows a permanent tendency to increase quality and manufacturing capabilities, which among other factors, drives them to invest in more advanced technology and knowledge. Investing in these two segments is said to be a guarantee of their increasing competitiveness in the products markets **(**Smidt 2006).

Many studies in the field of efficiency of CNC machinery are related to aspects influencing it directly or indirectly (Liberman 2010). Influence of the cutting instruments consuming effects on efficiency have been study by Ohuchi and Murase (2005). The monitoring and evaluation of consuming of cutting instruments or other CNC machine tools have been studied also by several other authors (Weis 1994; Lemaster et al. 2000; Iskra and Hernandez 2012).

Tonshoff et al. (1988) and Byrne et al. (1995) studied the requirements to be meet by sensors for process monitoring of CNC machine tools influencing direct or indirect the process efficiency.

Leondes (2004) analysing the rapidly-changing environment facing most firms today, as well as the shortened life cycles of many products and process technologies stressed the critical importance of the facility rearrangement and redesign in sustaining productivity and competitiveness. The general physical layout of manufacturing systems of the factory as a major determinant of a firm's efficiency is not taken into account, cause focus of the paper is related to time and labor costs efficiency of single operations.

In the field literature is shown that the use of CNC technology can have a positive impact in terms of lowering costs and the realization of large volumes of work in relatively short time and its continuous utilization with minimal operator involvement (FANUC 2012). Realization of large batch volumes is an important factor in lowering the costs of productions, specially the fix costs, which is not always the case of Albanian local market for wood products. The relatively small local markets and producing capacities of local companies are two important hindernisses for the extensive use of CNC technology (Suh et al. 2002) in the country.

The study analysis the drilling operations of wood-based panels, focusing in the comparison of the economic and technical parameters of drilling of particleboard panels (Jambrekovic 2004; Figuric 2000), used to produce the constructive parts of a window-case, on a CNC and a traditional drilling woodworking machine, using the same type of drill with identical groove (Dimoshi and Rrjepaj 1971; Nelson 1999).

The constructive parts of a window-case have been determined, as well as the nominal dimensions of these constructive parts, which are then fed into the software of a the three-dimensional CNC machine. Then, for the same furniture, the constructive parts are drilled with the a traditional tenoner drilling machine. The drilling time in this machine is measured by a chronometer. Another important parameter calculated for both machines is the number of employees engaged by both machines and related labor costs.

Further on, the results obtained have been compared among themselves, in order to revealed the differences in technical and economic parameters taken into account for both machines.

MATERIALS AND METHODS

As already mentioned in the introduction section this study is focused in the comparison of selected technical and economic parameters of drilling operation needed to be performed in the constructive parts of a window-case. The product called "Window-case 308" with dimensions 160x160x40 cm produced using high quality laminated particleboard panels was selected as subject of this study for comparison of technical and economic parameters. The particleboard panels used are of standard formats presented in the market with a width of 18 mm.

In the table 1 are given the nominal dimensions of the constructive parts of the "Window-case 308 that needs to be drilled. A more detailed picture of the product and its constructive parts if given in the figure 1 below.

Table 1. Dimensions of the constructive part of "Window-case 308"

No.	Constructive part description	Part dimensions	Pieces
1	Upper Panel	40mm x 160 mm	1
2	Door	39.35mm x 151.4mm	4
3	Sill	40mm x 160mm	1
4	Laterals	36mm x 151.4mm	2
5	Middle Laterals	35mm x 151.4mm	1

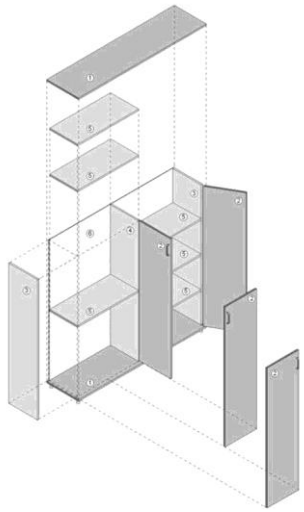

Figure 1. A detailed picture of the constructive parts of the window-case

Mill-drill three-dimensional CNC Machine Rover 22 Biesse

The ROVER 22 CNC machine consists of the machining part and the command part. In physical-visual terms, the machine is divided into the electronic part and the mechanical part. A NC 2000 program is installed on the computer of the machine, which enables the entry of numerical data, used in turn by the mechanical part of the machine. The program enables the operation of the machine, carrying out necessary technological operations.

ROVER 22 is a three-dimensional (three axes) CNC machine, with an axis length (X) = 3060 mm, an axis width (Y) = 1080 mm and an axis depth (Z) = 155 mm.

The pictures below show the ROVER 22 three-dimensional CNC machine. The picture on the left shows the ROVER 22 at the mill, while the picture on the right shows the configuration of the saw aggregate and the drilling group, which moves along the X, Y, and Z axes. It displays the mounting of drills and cutting tools, such as the milling tool that can be mounted as required to drill or mill. The machine displays a set of seven tools required during different technological operations, with their corresponding features and possesses automatic tool changing capabilities, which means that orders are entered and the appropriate tool will become operational. It possesses a disc that moves from 0 º to 90 º on the X axis, and drills for vertical and horizontal drilling on the X and Y axes.

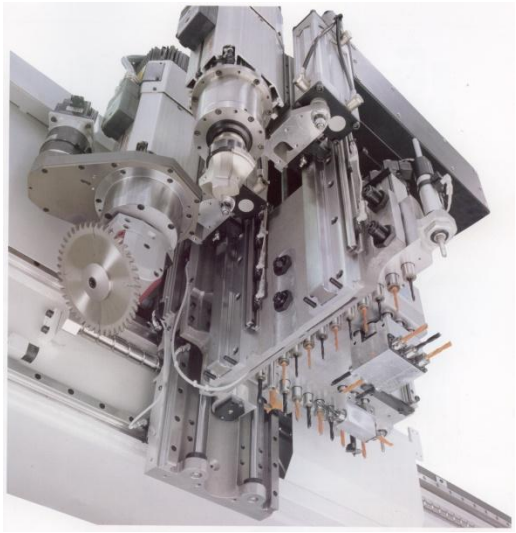

Figure 2. Three-dimensional CNC Machine ROVER 22

The following images display the drills used for drilling holes that will be used to connect the elements of the product, their colors and direction of rotation.

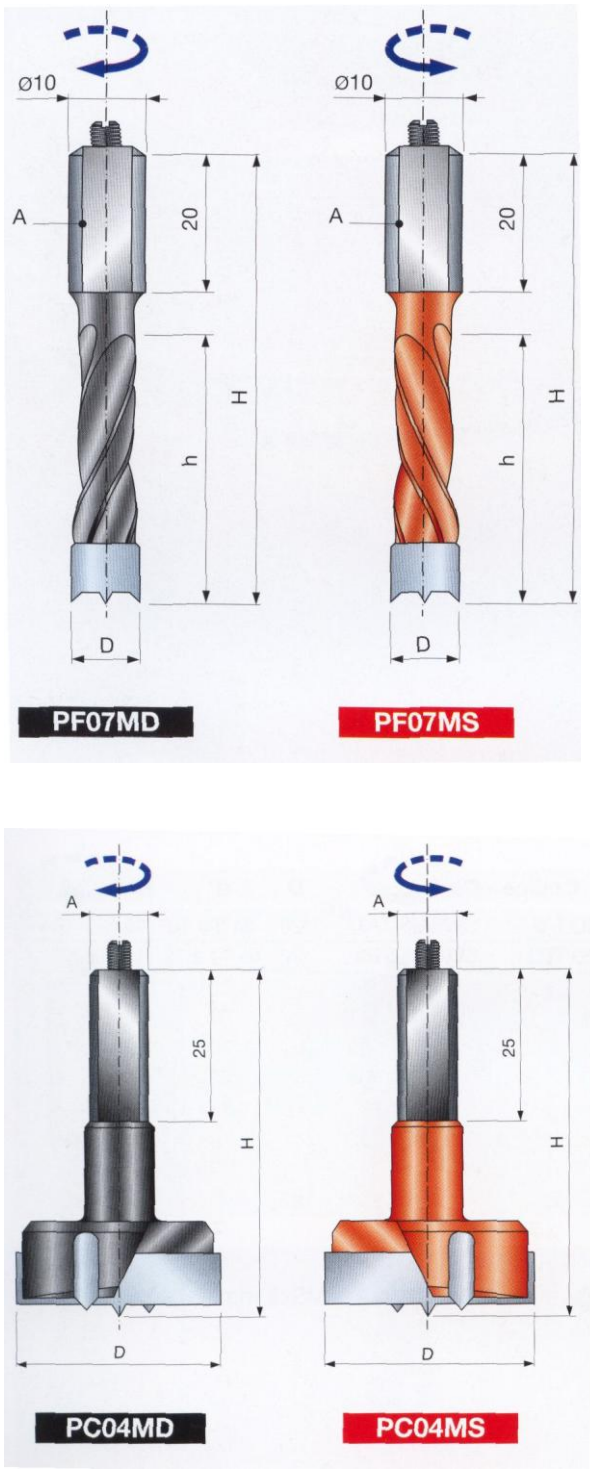

Figure 3. Drilling tools and their relative data and direction of rotation

In this machine are performed the drilling operations on the constructive parts of the product, preparing them for further fixings.

Traditional machine for drilling operation F21N Compact

The F21N Compact machine (Mark, 2006) has a total of 21 drill mounts, with different possibilities for horizontal, vertical and angular drilling. Elements are pressed through compressed air. Two workers are required to operate the machine, a master and an assistant. The drilling tools are drills with the same features as those of the three-dimensional CNC machine, which means that the same type of drills (see fig.2) have been used for drilling mounting holes for the constructive parts of the product in question "Window-case 308".

Figure 4. Traditional drilling machine F21N COMPACT

Drilling operations programming in the CNC machine

The nominal dimensions of the constructive parts of window-frame have been first determined. For both the traditional F21N COMPACT Machine and ROVER 22 CNC Machine there are no differences in these dimensions. In the case of ROVER 22 the nominal dimensions of the constructive parts are first fed into the software of the machine.

In the figure 4 are presented the coordinates collected during technological drilling operations of constructive parts of the product, as well as the geometry of the drilling points highlighted with red color in the CNC ROVER 22 machine.

In the figure 4 can be seen how the drilling operation is programmed for all constructive parts of the product. The figure 4 is showing the drilling points on the constructive part, namely the lateral parts, with dimensions of 1514 x 360 x 18 mm. The centers of coordinate angles are shown as S1 , S2 , S3 and S4, while working planes are presented as L1 , L2 , L3 and L4. In this case the coordinates of the horizontal drilling point are given in the small table in the right corner. In the first rowis given the angle S1, in the second row the plane L1, in third row axis length X = 0, forth row the axis width Y = 80 mm, fifth row the axis depth Z = PLPZ/2 (center of the drilling the same as half the thickness of the pannel, in the sixth row the drilling depth of 32 mm and in the last row the drill diameter of 8 mm.

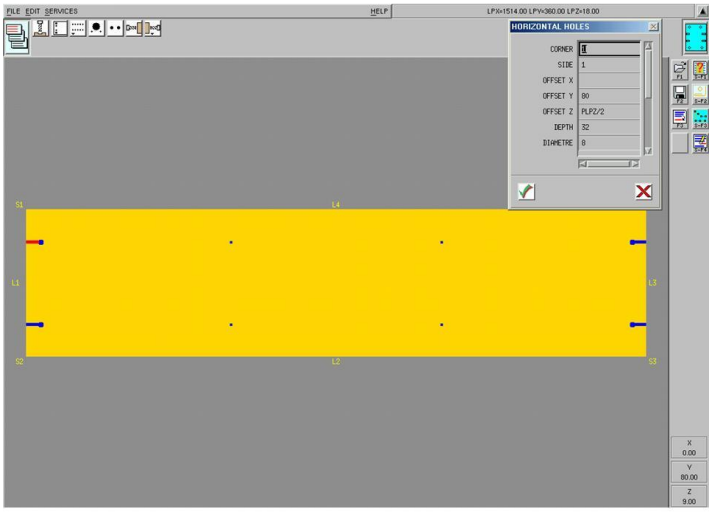

Figure 5. Drilling holes on the lateral constructive parts

For the sake of comparison, all technological drilling operations conducted in the ROVER 22 CNC machine, have been also conducted on the F21N Compact machine for the same product and constructive parts.

RESULTS AND DISCUSSION

The results related to the total time needed to perform all the single drilling operations on the constructive parts of the WINDOW-CASE for the CNC ROVER 22 BIEESE are measures automatically by the machine itself, meanwhile for the traditional drilling machine F21N COMPACT the total time of performing all the single cutting processes is measured using a chronometer.

In the tables 2 and 4 in addition to the nominal dimensions of the constructive parts of the WINDOW-CASE drilled in both machines, are given the total times needed to perform all the drilling operations in each of them.

For the CNC ROVER 22 is measured a time of 4.54 minutes for all five needed drilling operations performed in nine constructive parts of the product. The total time for the same operations performed by the traditional drilling machine F21N COMPACT is a longer time, respectively 23.2 minutes.

The results obtained from the measurements of the total time needed to perform all the single drilling operations on the constructive parts of the WINDOW-CASE, together with data related to the number of operators and assistants needed for each of the machines are used to calculate the hourly labor costs respectively for the CNC and the traditional drilling machine.

The labor cost/hour required to operate each of the machines are shown in the tables 3 and 5. These costs are usual for the local standards of the area, where is placed the woodworking factory in which the measurements of technical and economic parameters took place.

Table 2. Nominal dimensions of the constructive parts and drilling operations time for CNC ROVER 22

PRODUCT NAME		WINDOW-CASE item 308				PRODUCT DIMENSIONS		160x160x40 cm
Nr.	Constructive Parts	Type	Dimensions of constructive parts			Name of the Machine: CNC ROVER 22 BIEESE		
			thickness in cm	width in cm	length in cm	Tech. Operation: PANNEL Milling-Drilling	Installed Program: NC500	
						Time of Technological operation [min]		
						No. of parts	TYPE OF OPERATION	TIME [min]
1	Upper Panel	particleboard panel	1.8	40	160	1	Drilling	
2	Door	particleboard panel	1.8	39.35	151.4	4	Drilling	
3	Sill	particleboard panel	1.8	40	160	1	Drilling	
4	Laterals	particleboard panel	1.8	36	151.4	2	Drilling	
5	Middle Laterals	particleboard panel	1.8	35	151.4	1	Drilling	
6						9	TOTAL TIME [min]	4.54

Table 3. Measured time of drilling operations and calculated labor force costs for CNC ROVER 22

Nomination of Technological operations	Time of technical operation (min)	No. of required operators	Labor costs (€/h)	No. of required operator assistant	Labor costs (€/h)	Total work force costs (€/h)
Technical drilling operation	4.54	1	4.85	Not required	-	4.85

Table 4. Nominal dimensions of the constructive parts and drilling operations time for F21N COMPACT

PRODUCT NAME		WINDOW-CASE item 308				PRODUCT DIMENSIONS		160x160x40 cm
Nr.	Constructive Parts	Type	Dimensions of constructive parts			Name of the Machine: TRADITIONAL DRILLING MACHINE F21N COMPACT		
			thickness in cm	width in cm	length in cm	Tech. Operation: PANNEL Milling-Drilling		
						Time of Technological operation [min]		
						No. of parts	TYPE OF OPERATION	TIME [min]
1	Upper Panel	particleboard panel	1.8	40	160	1	Drilling	
2	Door	particleboard panel	1.8	39.35	151.4	4	Drilling	
3	Sill	particleboard panel	1.8	40	160	1	Drilling	
4	Laterals	particleboard panel	1.8	36	151.4	2	Drilling	
5	Middle Laterals	particleboard panel	1.8	35	151.4	1	Drilling	
6						9	TOTAL TIME [min]	23.20

Table 5. Measured time of drilling operations and calculated labor force costs for F21N COMPACT

Nomination of Technological operations	Time of technical operation (min)	No. of required operators	Labor costs (€/h)	No. of required operator assistant	Labor costs (€/h)	Total work force costs (€/h)
Technical drilling operation	23.2	1	2.5	1	1.5	4.0

From the tables 3 and 5 we can see that the hourly working force costs are lower for the traditional drilling machine F21N COMPACT with 4.0€, comparing with 4.85€ for the CNC ROVER 22, despite a higher number of operators and assisstants needed to operate the traditional drilling machine. The operators of the CNC machine are getting higher rates, cause of higher qualification requirements to operate the machine.

In the table 6 below are shown the differencies in the technical and economic parameters measures and calculated for both machines. The CNC machine is showing a clear advantage related to the time needed to perform the drilling operations, being more than 4 times faster than the traditional drilling machine.

Table 6. Differences in parameters measured between the CNC and traditional machine

No.	Parameters measured/calculated	Drilling operations with CNC machine	Drilling operations with traditional machine	Differences (%)
1	Time of operation per product in min.	4.54	23.20	-411
2	Number of required operators/assist.	1	2	-100
3	Cost of workforce per hour in €	4.85	4	+17.5
4	Cost of workforce per hour/operation in €	0.37	1.55	-319

Despite the smaller number of operators needed to operate the CNC machine, the costs of working force per hour are higher, when the drilling operations are performed with it. But this finding is showing not at all important, when the cost of working force per hour/operation is calculated. Because of the advantage in operations time of the CNC machine, the costs of drilling operations for the product with this machine are 3 times lower than with the traditional ones, respectively 0.37€ vs. 1.55€.

CONCLUSIONS

This study analysis the drilling operations in wood-based panels, in this case particleboard panels, used to produce the constructive parts of a window-case, focusing in the comparison of the economic and technical parameters of this single operation on a CNC and a traditional drilling woodworking machine. In both machines the drilling operations are performed using the same type of drill with identical groove.

The aim was in showing the advantages in time efficiency of single operations achieved by using the CNC technology in furniture making industry, specially in the processing of furniture parts.

Results of comparing the selected technical and economic parameters, respectively the total needed time of drilling oprations and the labor cost of this single operation, reveals clear differences in both parameters between the CNC and the traditional drilling machine. Regarding the time of performing the operation the ROVER 22 CNC machine is four times faster. The time efficiency of performing the drilling operations by the CNC machine is influencing positively the cost of labor per single operations. These costs are more than three times lower regarding the CNC machine, despite higher labor cost per hour.

Operations time savings constitute the main technical parameter taken into account by the study, and by observing the results obtained with CNC machines, it is clear that there is great advance in terms decreasing the operation times. This can enable the companies to a wide scale increase in productivity, minimizing the labor cost and particularly the fixed costs.

The annual value of depreciation of CNC machines is much higher compared to the traditional woodworking machines, due to their high initial investment cost, but cost benefits from much higher productivity should fully justify these costs. But to realize all these costs benefits the companies needs to increase their productive capacities, which are mainly influenced by the market. The local market in Kosova is relatively small in order to potentially enable the companies to consider the benefits of investing in CNC advanced technology.

There have been other aspects showing the advantages of using the CNC technology, which has been identified during the study, but not taken into account in terms of quantifying their benefits. The product chosen in the study processed with the CNC machine has a higher quality level enabling the companies to increase the revenues from the higher quality of the products.

Automatic optimization of the raw material, which is not possible in traditional woodworking

machines, has an increasing effect on the level of the raw material use.

Increasing the time efficiency of some production operations through using CNC technology can positively influence the time efficiency of other operations as internal transport of furniture parts, parts assembling, etc.

Only through analysing the operations time saving the study is showing the importance of investing in advanced CNC technology, especially for final wood processing, in order increases the competitiveness of wood manufacturing companies in the local and regional market. The companies that will consider these investments should take into account the high need to invest also in high qualification of the labor force and consider changing in the general physical layout of manufacturing systems of the factory as another major determinant of a firm's efficiency, which is also not taken into account by the study.

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