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Correspondence

Wood Industry and Engineering Journal
Karadeniz Technical University
Faculty of Forestry, Department of Forest Industry Engineering
Kanuni Campus, 61080, Trabzon / TURKEY

Phone: +90 462 377 3154
Fax: +90 462 325 7499

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Contact

engin_gezer@yahoo.com
iaydin@ktu.edu.tr

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EVALUATION OF TOOL PATH STRATEGIES IN CNC WOODWORKING MACHINES AND A CASE STUDY

Özer Özçelik[1], Küçük Hüseyin Koç[2]

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Abstract

Since computerized numerical controlled (CNC) machines began to be used in the manufacturing industry, accurate determination of tool path strategies has always been an important problem area. In addition to the increasing design expectations especially in products and parts, developments in CNC machines have increased the efficiency expectation in tool path applications. The tool path can also vary according to the nature of the work and the geometric structure needed. Different tool path strategies can be used depending on product structure and machine characteristics in different sectors. The geometry of the workpiece to be machined, especially designed for machining complex shaped parts, plays an important role in determining the cutting tool path and tool to be used. In addition, the preferred tool path strategy raises issues such as reducing manufacturing costs, reducing manufacturing time and improving surface quality. In this context, the parameters such as the form of the workpiece, the quality of the workpiece, the characteristics of the cutting tool, the machine characteristics, the cutting conditions are among the main factors to be considered in the tool path evaluations.

In this study, tool path strategies for a sample piece of product were evaluated in a CNC woodworking machine. A three-axis CNC machine was chosen for the application. For this purpose, first of all, product part is modeled in CAM program and tool path strategies are developed on product design. These strategies were applied on CNC woodworking machine and the results of preferred tool path strategies were evaluated with comparative analysis. As a result of the research, the approaches that can be applied in determining the correct way of team strategies and the benefits that can be obtained are discussed.

Corresponding Author

Özer Özçelik
ozerozcelik@trakya.edu.tr

Phone: +90-284-2240283
Fax: +90-0284-2240288

[1] Trakya University, Department of Material and Material Processing Technologies, Edirne, Turkey
[2] Istanbul University-Cerrahpaşa, Department of Forest Products Engineering, Istanbul, Turkey

EVALUATION OF TOOL PATH STRATEGIES IN CNC WOODWORKING MACHINES AND A CASE STUDY

Özer Özçelik
ozerozcelik@trakya.edu.tr
ORCID : 0000-0002-2799-387X

Küçük Hüseyin Koç
hkoc@istanbul.edu.tr
ORCID : 0000-0001-6370-2016

1. Introduction

It is true that CNC machines have an extremely complex technology. On the other hand, it is very easy to learn and use the machine, even for those who have not yet met with the CNC machines. A person who has experiences on conventional machine tools, knows the principles of chip removal, four operations in mathematics, basic computer knowledge and the concept of coordinates, learns how to program and operate the machine after an average of 16 hours of training (Amasya University, 2013).

CNC machines, which are vital for the manufacturing industry, contain many complex issues that require long-term work. Some of these topics are cutting tool characteristics and selection, machine cutting parameters, axis movements, material properties and toolpath strategies. An innovation in one of these subjects, which have been studied and developed for years, causes the other areas to be affected in parallel. Toolpath strategies have also been continuously developing for years in parallel with the developments in other fields.

2. Materials and Methods

In the sample study, 18 mm medium density melamine faced fiberboard (MDF) was used as the material. In addition, a 2100x2800 mm flat and vacuum table CNC machine with tool change was used in the experiments. In the example application, a 5 mm diameter flat tip cutting tool is used.

The part to be used for the sample application on the CNC machine was modelled in both ArtCAM and Fusion 360 programs, as toolpath strategies of two different CAD / CAM programs were used. While creating the tool path strategies in both programs the cutting tool properties (t) speed (S) cutting speed (G1), idle movement speed (G0), cutting direction (M03), such as steps and steep side-step cutting parameters were kept the same.

For each tool path determined for the sample study, the workpiece was first modelled in the CAD program and then G code was created in accordance with this tool path. After the generated G codes were transferred to the machine, the sample was processed in the cutting parameters determined on the workpiece. After repeating this process for all the determined toolpaths, the data obtained were discussed in the findings section and their comparisons were examined through the table data.

3. CNC Technology

The general purpose of CNC machines is to give the desired shape to a material in the form of a raw material. Depending on the type of machine, the desired shape can be given as a result of tool movement, part movement, or tool and part moving together. CNC machines perform the desired operations with the programs in which these movements are shown with "G", "M", "S" and "T" codes. Programs consisting of "G", "M", "S" and "T" codes describe the paths the tool. Therefore, tool paths have an important place in CNC machines (Özçelik, 2006).

As with every system, CNC machines and systems have some advantages and disadvantages. These advantages and disadvantages are:

3.1. Advantages of CNC Machine Tools

- The adjustment time of the machine is very short when compared with some clamping molds, gauges etc. used in conventional machines.
- Loss of time caused by adjustment, measurement, control, manual movement, etc. is eliminated.
- Since the human factor is not very effective in manufacturing, serial and precise manufacturing is possible.
- Sometimes or no need for qualified people.
- Machine operations have a high precision.
- The working tempo of the machine is always high and the same.
- All kinds of consumption (electricity, labor, material, etc.) are minimized.

- All kinds of personal errors caused by the operator in manufacturing have been eliminated.
- The system is cheaper since expensive elements such as mold, gauge, template etc. are not used.
- Less space required for storage.
- The transition to new parts manufacturing is faster (Olam, 2012).

3.2. Disadvantages of CNC Machine Tools

- A detailed manufacturing plan is required.
- Requires an expensive investment.
- The hourly price of the machines is high.
- Compared to conventional benches, they require more meticulous use and maintenance.
- High quality cutters with high cutting speeds should be used.
- Periodic maintenance should be done regularly by experts and authorized persons (Olam, 2012).

3.3. Axes on 3 Axis CNC Machines

Cartesian coordinate system is used in the axis definitions of CNC machine tools. In this system, the axes are indicated by the letters X, Y and Z. The intersection points of these 3 axes are the origin (Amasya University, 2013).

The most commonly used method in axis definitions is the Right Hand Rule. In this rule, the thumb refers to X, index finger to Y, and middle finger to the Z axis. The intersection point of these three axes is the palm. The tips of all three fingers show the positive (+) directions of these axes and the opposite (-) directions (Figure 1) (Amasya University, 2013).

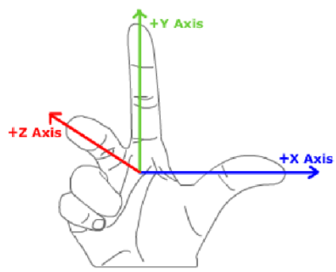

Figure 1: Right hand rule (Amasya University, 2013).

4. Team Path and Creation

4.1. Definition of Toolpath

If it is defined in general, the route that the cutting tool follows by removing chips on the workpiece is called the tool path. Many tool path strategies have been developed over the years according to the nature of the work to be done and the characteristics of the cutting tool to be used. There are certain stages in creating a tool path. First, the workpiece to be processed is modelled in a CAD (Computer Aided Design) program. The workpiece is usually modelled in 2D or 3D. The tool path strategies used in 2D and 3D models differ. The workpiece with completed modelling is converted to G,S,M,T codes in order to be processed on the CNC machine. Different conversion processes are required on machines of different brands. Although the G,S,M,T codes that are required for CNC machines to work have universally the same meanings and functions, CNC machines produced by different brands use different converters (post process) because the software and machine features are different. Some machines automatically recognize drawings with the dxf extension and perform the conversion process themselves. Again, most of CNC machines used in the furniture industry allow minifix holes to be drawn with pre-drawn cover models or some jobs that require only linear cutting in 2D with their own drawing program and create a tool path.

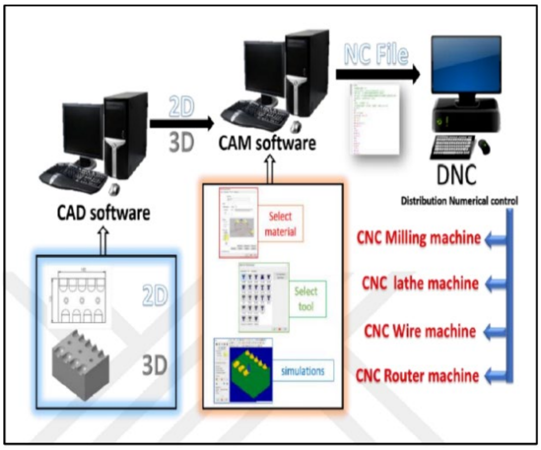

Figure 2: Process stages of CNC machine from design to production stage (Alabayed, 2018).

The features of the cutting tool are of great importance in determining the tool path. Features such as the quality of the cutting tool to be preferred, diameter, cutting direction, insert depth, tool length, heating and cooling properties, cutting speed characteristics, rotation speed feature and form are all factors that should be taken into consideration in tool path creation.

4.2. The Most Frequently Used Commands on A CNC Machine

Many commands are used in CNC machines. As the commands are determined according to the nature of the work done, the commands can be diversified and customized according to the sector where the work is performed. For example, since the material processed in the machinery industry is mostly metal, a certain heat occurs when it comes into contact with the cutting tool and this heat must be minimized for a qualified job. Therefore, CNCs with water, oil and air cooling are generally used in the machines used in the machinery industry. However, since wood is a soft material in the furniture industry, there is not much heat. Therefore, the cooling feature of the machines used in the furniture industry is either with air or not at all. This situation requires using additional commands on machines used in the machinery industry. The same is necessary in the furniture industry. The machine is designed differently for the drilling processes on the lateral surfaces required for minifix and similar fasteners in the furniture industry, and different commands must be used from other sectors to use the hole units on these lateral surfaces.

The most frequently used commands in the furniture industry are as follows;

G0: When the machine is not cutting, G0 command is used to move from one position to a different position. Under normal conditions, high speed motion is performed to avoid loss of time during cutting.

G1: It is the command used for the machine to make linear cutting by removing chips. After the command is entered, the machine continues by making a linear cut up to the X and Y coordinates.

G2: It is the command used for the machine to cut curvilinear clockwise. With the command, values such as X, Y, Z values and the diameter or radius of the arc to be cut, the center point, the X and Y distance from the end point of the arc to the center point of the arc are requested. It is necessary to write one or more of these values, which are specified according to the broadcast characteristics to be cut, into the program.

G3: This command works in the same way as the G2 command. Used for counter clockwise cutting only.

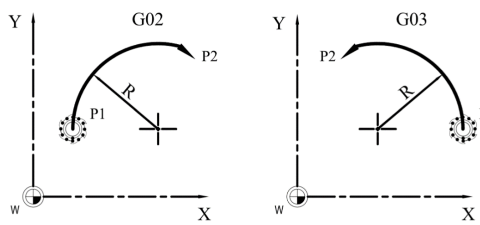

Figure 3: G2 and G3 circular interpolation direction determination (Programming in CNC Milling, 2006).

G17: It is used for the selection of the surface to be treated. The G17 command specifies to work on the top (XY) surface.

G18: It is necessary to work on the lateral surface in boring and orifice processes required for fasteners such as Minifix. Surface selection should be made in CNC machines that allow working on the side surface. The G18 command states that it will work on the ZX lateral surface.

G19: G19 command indicates that it will work on YZ lateral surface.

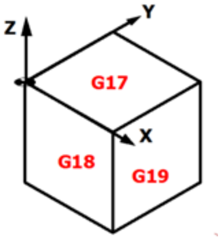

Figure 4: Planes in CNC machines

G90: It indicates that the G codes created for the workpiece to be machined are created in the absolute coordinate system and will be processed in this system.

G91: It indicates that the G codes generated for the workpiece to be machined are created in the relative (incremental) coordinate system and is processed in this system.

M03: Indicates that the spindle on which the cutting tool is mounted is rotated clockwise.

M04: Indicates that the spindle with the cutting tool rotates counter clockwise.

M30: It is used for the end of the program. When the work done by the CNC machine is finished, the program is written at the end. This indicates that the work is done.

T: Used for Tool Number. In some CNC programs, "A" command is used for the tool.

S: It expresses the number of revolutions of the spindle per minute.

5. Most Preferred Team Road Strategies

There are 2 types of toolpath tracking strategies in a 3 axis CNC machine. These strategies are 2D toolpath and 3D toolpath strategies. In fact, the toolpath strategies used in both drawing types basically work on the same logic. The difference of 3D toolpaths from 2D toolpaths is that curved surfaces cannot be machined in a 2D drawing. In a 3D drawing, on the other hand, as the drawing is three-dimensional due to the structure of the drawing, depending on the form of the drawing, the cutting tool moves by removing chips on the workpiece while moving up and down to different cutting depths (Z) on flat, angled and inclined surfaces. This makes toolpath creation for a three-dimensional model more complex and difficult. CNC machine manufacturers and CAD / CAM program developers generally use the same toolpath strategies. However, in recent years, especially CAD / CAM programs have developed new toolpath strategies according to the field of activity, the nature of the work, workpiece and cutting tool characteristics, cutting parameters. It was possible to see a different toolpath option in each CAD / CAM program. This study focused on 2D toolpaths.

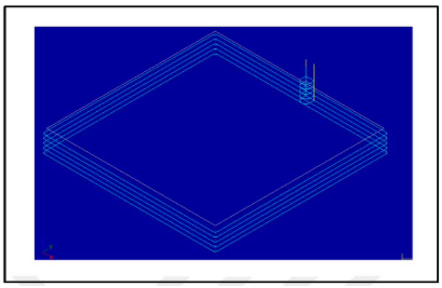

Figure 5: 2D Toolpath example (Alabayed, 2018).

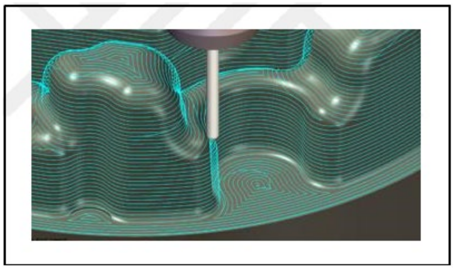

Figure 6: 3D toolpath example (Alabayed, 2018).

As mentioned above, basic toolpath strategies have been used for years. The basic logic of these strategies has changed little. The basic logic of the toolpaths is based on cutting or scanning the workpiece. The most preferred 2D toolpath strategies are as follows.

5.1 2D Toolpath Strategies

a. Zigzag Parallel Toolpath Strategy

In the zigzag strategy, the cutting tool continues in a zigzag from the starting point to the end point where it dives into the workpiece. Thus, it scans the area where it cut. If the contour of the scanned area is in a different geometric structure, the cutting tool can draw zigzags in accordance with this geometric shape. It can cut or scan clockwise or counter clockwise according to the cutting direction of the cutter blade.

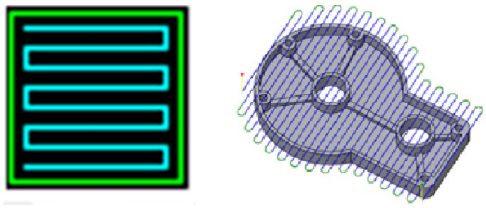

Figure 7: Zigzag parallel toolpath strategy

b. One-Way Cut Toolpath Strategy

In the one-way cutting strategy, the cutting tool cuts only in one direction. For example, in the Zigzag strategy, the cutting tool moves in the + X –X or + Y –Y directions, while in this strategy the cutting tool does not cut in the X direction if it cuts in the + X direction. The same is true for the Y axis.

Picture 8: One way cutting strategy

c. Parallel Spiral Toolpath Strategy

In the Parallel Spiral Tool Path Strategy, the cutting tool is cut by following a route in the form of nested squares from the outside to the inside or from the inside to the outside. The side step size used in the tool path varies depending on the tip form of the cutting tool. If cutting is done with a flat tip cutting tool, the side step is usually given at 50% of the tool diameter. If the cutting tool has an oval insert, the side step rate varies between 1% and 10%.

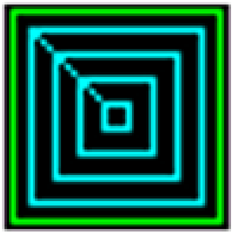

Figure 9: Parallel spiral toolpath strategy

d. Spiral Toolpath Strategy

The spiral toolpath strategy is the tool path that takes the center point of the workpiece as the center and it is in a spiral form around this center, from the outside to the inside or from the inside to the outside. Very effective results are obtained in the processing of workpieces with mostly circular forms.

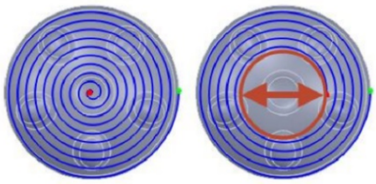

Figure 10: 2D spiral toolpath strategy (CAM Milling on 2½ Axis, 2019).

e. Outline Spiral Toolpath Strategy

This toolpath strategy is mostly used in workpieces with different contour forms. It is a tool path in a spiral form from outside to inside or from inside to outside according to the form structure of the contour shape. Since there is a seamless connection between the tool paths, the cutting tool only makes one dive and one exit into the material.

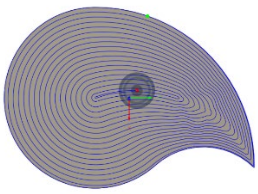

Figure 11: Outline spiral toolpath strategy

f. Drilling Toolpath Strategy

In the furniture industry, fasteners, shelf pins and holes that need to be drilled into the workpiece for different purposes can be drilled with this strategy. The hole diameter is drawn as it is in the design program and the CAM program automatically defines the hole diameter. In this strategy, both vertical and horizontal holes can be drilled. In order to be able to drill horizontal holes, the CNC table must be suitable for horizontal drilling and at the same time the CNC machine must have horizontal hole attachments.

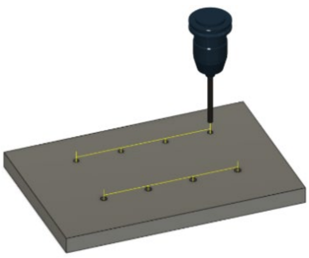

Figure 12: Drilling strategy

g. Writing Toolpath Strategy

With this strategy, text can be written in both 2D and 3D form workpieces. In this strategy, generally V-tip cutting tools are used.

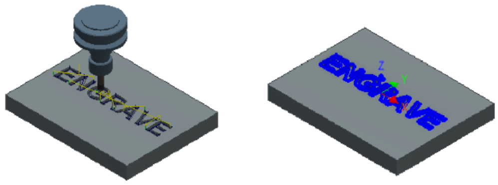

Figure 13: Writing strategy

6. Findings

The CNC machine used for example applications and the cutting tool used are shown in Figure 14.

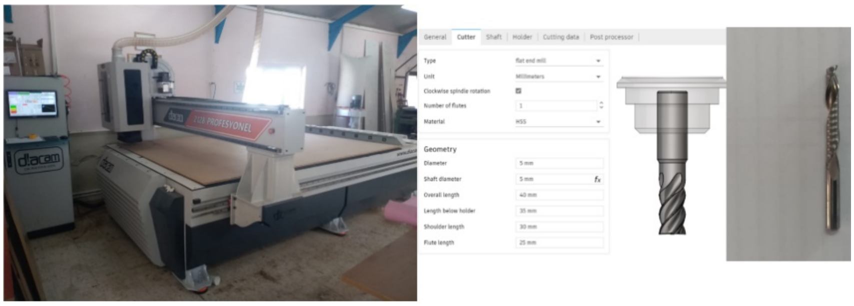

Figure 14: CNC machine and cutting tool features used in sample applications

The sample workpiece is designed as a part with different geometric forms in order to use different toolpath strategies. A total of five tool path strategies have been determined, and the CAM images of these tool paths and the results obtained after the workpiece is processed are as follows.

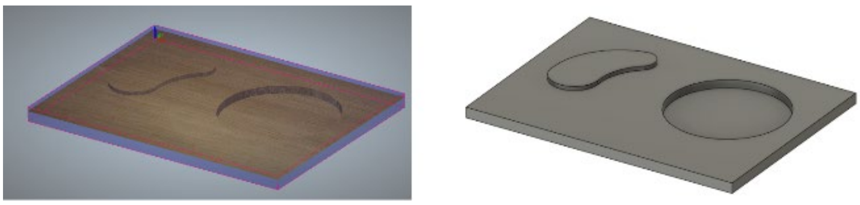

Figure 15: Sample part drawing in ArtCAM and Fusion 360

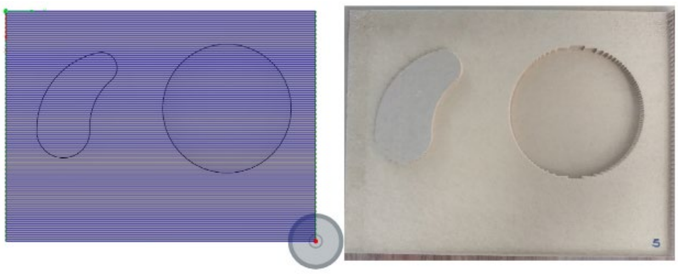

Figure 16: Zigzag parallel toolpath strategy

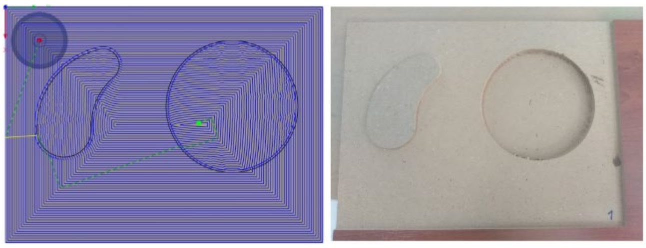

Figure 17: Parallel spiral toolpath strategy

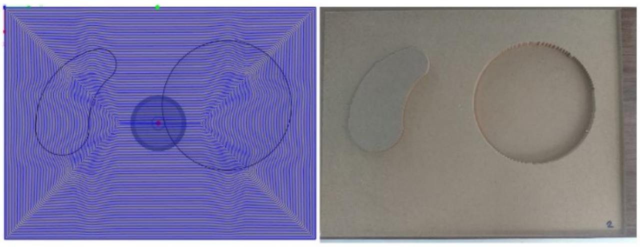

Figure 18: Outline spiral toolpath strategy

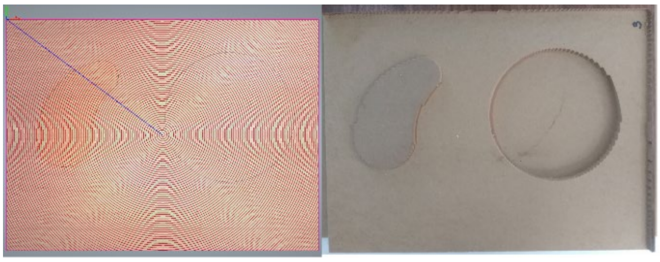

Figure 19. Spiral (classic) toolpath strategy

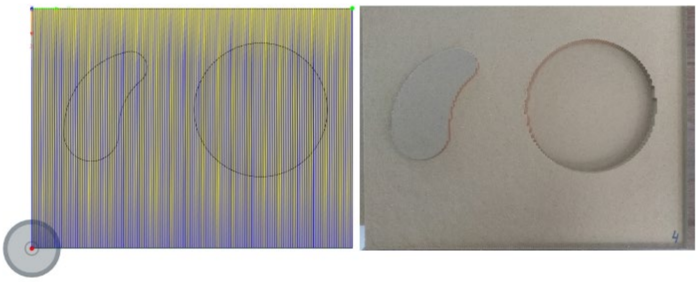

Figure 20. One way parallel toolpath strategy

A total of 5 toolpath strategies have been determined for the sample workpiece. In tool paths, machining time, cutting length, cutting speed, diving and exit speed of the cutting tool to the workpiece, steep step and side step distance were taken into consideration. The cutting speed, speed, blade diameter, diving and output speeds of the cutting tool to the workpiece and the side step and vertical step distance of the blade were kept constant. Below are the data obtained from the tool paths given in tabular form.

Table 1: Obtained Data of Tool Path Strategies

No	Toolpath Strategy	Processing Time	Tool Path Length	Cutting Tool Diameter (mm)	Turnover (S)	Cutting Speed (F) (mm / min)	Diving Speed (mm / min)	Output Speed (mm / min)	Upright Step (mm)	Side Step (mm)
1	Zigzag	11 dk 30 sn	38,8 mt	5	15000	4000	1000	1000	max.	2,5
2	Parallel Spiral	11 dk 31 sn	39,8 mt	5	15000	4000	1000	1000	max.	2,5
3	Outer line Spiral	16 dk 20 sn	57,9 mt	5	15000	4000	1000	1000	max.	2,5
4	Spiral (Classic)	15 dk 22 sn	60,6 mt	5	15000	4000	1000	1000	max.	2,5
5	One Way Parallel	14 dk 25 sn	77,6 mt	5	15000	4000	1000	1000	max.	2,5

7. Conclusion and Recommendations

In the studies, no surface roughness device and method were used to determine the surface roughness, and an opinion about the surface roughness was reached according to the eye examination. In addition, a 5 mm flat tip cutting tool was preferred for all sample applications and 18 mm medium density melamine coated fiberboard for the workpiece.

According to the data obtained as a result of the studies, the tool path strategy with the longest processing time is the Outer Line Spiral. This tool path is followed by Classic Spiral and One Way Parallel. The Zigzag Parallel and Parallel Spiral methods have almost the same processing times. Considering the margin of error of machining time, it can be said that these two toolpath strategies have the same machining time.

When the data is examined on the tool path length value, the toolpath strategy with the longest cut length is the One Way Parallel strategy. Since this tool path only cuts in one direction, every time it reaches the end of the cutting direction, it moves idle and returns to the beginning at maximum speed and starts cutting again. Because of the excess of these idle movements, the cutting length is the longest tool path.

The other longest toolpath in terms of toolpath length values is the Classic Spiral Method. The reason why the classical spiral method is one of the longest tool paths in terms of both processing time and processing length is due to the mismatch of the cutting strategy and the workpiece. Since the spiral toolpath strategy is based on a continuous spiral logic, it continues to spirally cut until the last metal removal command, regardless of the contour form of the workpiece. Since the workpiece used in practice has a rectangular form, after a point the cutting tool has to move freely on the short side of the rectangle. This causes unnecessary loss of distance and time. Therefore, while other toolpaths move only in areas where they remove chips, this tool path moves a significant proportion of the cut length in idle mode.

As a result of all evaluations, it has been observed that toolpaths with parallel machining strategy work in a shorter time and at a shorter machining distance than spiral strategies. It has been observed that the desired surface quality cannot be achieved in all tool paths, especially in the contours of circular shaped surfaces. A second cutting strategy has to be determined in order to smoothen these surfaces.

Although a single type and single-form cutting tool was used in the studies, more than one cutting tool and cutting tools with different end forms should be used according to the form of the workpiece in order to produce more qualified works. Apart from this, cutting strategies should be divided into roughing and finishing operations in order to prevent rapid wear of the cutting tool. However, this process does not only increase the surface quality but also increase the cutting time and cutting length.

While cutting the workpiece, minimizing unnecessary starts and dives of the cutting tool will positively affect the cutting time. While some CAM programs provide the user with diving and take off options, some of them automatically determine this feature.

The sharpness of the preferred cutting tool positively affects the surface roughness. In addition, the cutting tool should be preferred according to the cutting strategy to be made. For example, for a process that only be scanned, the choice of a large diameter cutting tool instead of a narrow diameter cutting tool would increase the side step distance, so there would be a positive improvement in terms of cutting time and cutting distance.

The revolution and speed properties of the cutting tool used should be well known and values should be given according to these features.

It is very important that the workpiece to be machined is stably attached to the CNC machine. It is very important for the quality of the work that the workpiece does not move while the CNC machine is cutting.

Many CAD / CAM programs are used in the industry. Some programs contain both programs, while some programs contain only one. It is very important to use the correct CAD / CAM program to determine the correct tool path according to the nature of the work to be done.

As a result of all these evaluations and literature researches, it has been observed that the toolpath studies specially developed for the furniture industry are not at a sufficient level. In this context, the necessity of scientific studies to develop toolpath strategies for the works that are used extensively in the furniture industry has emerged.

8. Acknowledgments

This study was presented as a full text at the VI. International Furniture Congress held by Karadeniz Technical University, Trabzon.

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EFFECTS OF WOOD SPECIES OF THE DOWELS AND FIBER WOVEN FABRIC TYPES ON BENDING MOMENT RESISTANCE OF L-SHAPED JOINTS

Abdurrahman Karaman[1], *Mehmet Nuri Yıldırım*[2]

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Keywords
Bending moment resistance
Wooden dowel
BFRP
GFRP
Two-pin dowel joint

Abstract

This study investigated the bending moment resistance of L-Shaped, two-pin dowel joints connected with Scots pine dowel (*Pinus slyvestris* Lipsky), beech dowel (*Fagus orientalis* Lipsky), chestnut dowel (*Castanea sativa* Mill.) and oak dowel (*Quercus petraea* Lieble) and reinforced with basalt and glass woven fabrics (BFRP and GFRP). The tests were carried out to determine the bending moment resistance of dowel joints. As a result of bending test, it was determined that one layer and two surfaces the reinforced with fiber woven fabrics increases the mechanical performance of furniture fasteners according to obtained data from tests conducted on the L-Shaped, two pin dowel joints. Experimental results showed that joints constructed of Oak wood had the higher bending moment resistance than Beech wood. Joints connected with Oak dowel had the highest bending moment resistance, and the joints of Scotch pine dowel had the weakest bending moment resistance. The bending moment resistance value of oak was approximately 12%, 25% and 55% higher than for joints constructed with chestnut, beech, and Scots pine, respectively, The bending moment resistance value reinforced with BFRP (79.77 N.m), and the lowest was in unreinforced joints (49,36 N.m). The mean bending moment resistance of reinforced joints (BFRP, GFRP) was 14% and 62% higher than unreinforced samples (control), respectively. In general, it has been found that the bending moment resistance of dowel joints is influenced by wood species, wooden dowel species and fiber woven fabric types.

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Corresponding Author
Abdurrahman Karaman
abdurrahman.karaman@usak.edu.tr

Phone: +90-276-2212150
Fax: +90-276-2212151

[1] Uşak University, Banaz Vocational School, Department of Forestry and Forest Products, Uşak, Turkey
[2] Karabük University, Safranbolu Şefik Yılmaz Dizdar Vocational School, Department of Interior Design, Karabük, Turkey

EFFECTS OF WOOD SPECIES OF THE DOWELS AND FIBER WOVEN FABRIC TYPES ON BENDING MOMENT RESISTANCE OF L-SHAPED JOINTS

Abdurrahman Karaman
abdurrahman.karaman@usak.edu.tr
ORCID: 0000-0002-5925-7519

Mehmet Nuri Yıldırım
mnyildirim@karabuk.edu.tr
ORCID: 0000-0002-0180-4479

1. Introduction

Wood material is among the most widely used building materials due to the fact that it is renewable, low cost, natural, easy to recycle and aesthetic, It is known that one of the most important advantages of reinforcement with basalt and glass fabrics is to strengthen and repair the wood material, Although the application of these methods brings a cost burden to the user, it increases the useful life of the wood structure, For this aim, it is an ideal reinforcement element for wood materials since it has a high degree of hardness and higher strength compared to its light weight and it is a non-abrasive corrosion resistant flexible material which ensures the reduction of long-term maintenance costs and provides fast installation on site, Also, these materials demonstrate high durability in corrosive environments thanks to their high resistance to fatigue, The production of reinforced wood materials with high economic value and their increasing use can benefit economically.

Joints represent a critical part of the structure of furniture. The joints provide continuity to the member and strength and stability to the structure. Proper joint design is important so that joints can carry a load safely in service conditions without excessive deformation or failure (Hajdarevic and Martinovic 2014). The mechanical strength of a piece of furniture depends mostly on the strength of its joints. (Gaff and Babiak 2017). With a suitable Shaped of joint, it is possible to achieve considerable simplification of the structure itself and improve its integrity (Svoboda et al. 2015). The mechanical behaviour of wooden joints is a complex problem governed by a number of geometric, material and loading parameters (e.g. wood species, fastener diameter, end distances, edge distances, spacing, number of fasteners, fastener/hole clearances, friction) (Eckelman 2003).

L-shaped corner-joint is one of the most important furniture structures Shaped manufactured and used nowadays for connecting leg, transom, and handrail. There is an important joint style usually used in a L-shaped corner-joint which is called butt joint with dowels (Ke et al. 2016). Dowel joints are widely used Types of structural joints, both as (load-bearing structure) connections and also as simple part positioning elements. Two-pin dowel joints are among the most important structural joints in upholstered furniture frame construction (Segovia and Pizzi 2012). Calculating the bending moment resistance and the strength of the dowel joints is a complex problem depending on many factors. The most significant of these factors are wood species, dowel length, depth of dowel embedment, dowel Shaped, hole diameter, distance between holes, number of dowels, the method of loading, and the strength of glue lines appearing in the joint (Eckelman 2003).

Hajdarevic and Martinovic (2014) investigated stress and strain analysis of double-dowel case-Shaped furniture corner joint. They showed that dowel spacing, distance between the dowels, and edge of board have considerable impact on the stress state of the face and edge member; joints became stiffer when distance between the dowels and board edge were rationally defined. Georgescu and Bedelean (2017) reported that the compressive and tensile strengths of heat- treated dowel joints increases when the dowel length increases, the distance between holes increases, and the ratio of dowel embedment in the rail of the joint decreases. Chen and Lyu (2018) determined optimum parameters for double dowels in medium density fiberboard components, and the maximum value of the strength of joints loaded in tension and compression bending. and found that the optimal parameters for double dowel joints with maximum bending strength were determined a dowel diameter of 10 mm, an interference fit of 0,10 mm and a spacing of 48mm. The results revealed that the optimal parameters for double dowel joints with maximum tensile strength were a dowel diameter of 10mm, an interference fit of 0,20mm, and a spacing of 64mm.The optimal parameters for double dowel joints with maximum bending strength were a dowel diameter of 10mm, an interference fit of 0,10mm and a spacing of 48mm. Chen et al. (2018) investigated the effects of dowel penetration depth, shear strengths of connection member and dowel materials, dowel surface texture, and member grain orientation on ultimate direct withdrawal loads of single dowels withdrawn from wooden materials, and the results showed that the mean values of ultimate direct withdrawal loads of dowels increased significantly as dowel penetration depth increased from 12.7 to 38.1 mm at increments of 6.35 mm. Uysal and Haviarova (2018) investigated the estimation of reasonable design values for two-pin moment-resisting dowel joints by using the lower tolerance limits (LTLs) method. They showed that the dowel diameter and length for double dowel joints with the shear strength were determined a dowel diameter of 12 mm for red oak and 13.1 mm for white oak, dowel lengths were 31.5 mm for red oak and 28.5 mm for white oak. Georgescu et al. (2019) investigated the influence of dowel diameter, adhesive consumption, and dowel length on the bending moment resistance of heat-treated wood dowel joints using response surface methodology (RSM) and determined that the dowel length and dowel diameter had significant effects on the bending moment resistance of heat-treated wood dowel joints. Hao et al. (2020) studies focused on the quantitative effect of dowel dimension, dowel position, loading distance on bending moment resistance. The results showed that the dowel space has positive effect on the bending moment resistance while the impact of loading distance can be neglected. But the top dowel, rather than bottom dowel, plays a critical role in deciding joint moment resistance. Increasing dowel diameter and length, fortifying dowel rupture and withdrawal strength, enlarging dowel space, or moving bottom dowel far away from the bottom edge will promote the joint performance. Podlena et al. (2020) compared the withdrawal strength of plain dowels, and the spiral dowels manufactured from beech (*Fagus sylvatica* L.) and oak wood (*Quercus robur L.*) and found that that the higher withdrawal strength of spiral dowels was statistically significant and the lowest withdrawal strength was found for plain beech dowels (3 MPa), which, in addition to higher relative humidity (RH 85%), was also caused by a combination of plain structure and greater diameter of the dowels.

To overcome the inferior mechanical properties of wood elements, fiber reinforced polymer (FRP) composite (Johns and Locroix, 2000) can be one of the solutions. The commonly utilized FRP composites as reinforcement for wood beams are carbon FRP (CFRP), E-glass FRP (GFRP) and aramid FRP (AFRP) (Johns and Locroix, 2000; Borri et al. 2005; Wang et al. 2019). However, the production processes of these fibers are the initial costs are still high. Recently, mineral-based natural FRP, such as BFRP has been introduced. BFRP has low material cost, high fire resistance, good thermal, electrical and sound insulating properties (Fiore et al. 2015). Moreover, their specific mechanical properties are comparable with, or better than, those of E-glass ones (Fiore et al. 2011).

Basalt-based materials are environmentally friendly and non-hazardous. The current production technology for continuous basalt fibres is very similar to that used for E-glass manufacturing. The main difference is that E-glass is made from a complex batch of materials whereas basalt filament is made from melting basalt rock with no other additives and, as a consequence, with an advantage in terms of cost. Their specific mechanical properties are comparable with, or better than, those of E-glass ones. The GFRP material value of density, elasticity modulus, tensile strength and elongation to fracture were 2,6 g/cm^3, 76 GPa, 2,0 GPa, and 2,5 %, respectively (Fiore et al. 2011). The BFRP value of density, elasticity modulus, tensile strength, and elongation to fracture were 2,8 g/cm^3, 89 GPa, 2,8 GPa, and 3,2 %, respectively (Colombo et al. 2009). Dorigato and Pegoretti (2012) explained that the basalt fibers have exhibit mechanical properties fully comparable with those of glass fibers, the elastic modulus of basalt and the tensile strength were greater than glass fibers.

Recently, A great deal of investigations has been studied wooden reinforced with the FRP (Yerlikaya 2013; Osmannezhad et al. 2014; Yerlikaya 2014; McConnell 2015; Raftery and Kelly 2015; Schober et al. 2015; Brol and Wdowiak 2017; Brol et al. 2018; Zhou et al. 2018; Gaff et al. 2019; Wang et al. 2019; Yerlikaya 2019; Zhou et al. 2019; Zhou et al. 2020; Wdowiak-Postulak, 2021).

On the bending moment resistance of T-type, two-pin dowel joints with reinforced basalt fiber woven fabrics (BFRP) are not applied and it is considered that there is a deficiency in the literature. The reinforcement with BFRP reinforced joints in frame-type furniture is a new research topic.

The aim of study is to determine the effects of wood species of the dowels and fiber woven fabric Types (BFRP and GFRP) on the bending moment resistance of the L-shaped joints, two-pin dowel joints.

2. Materials and Methods

2.1 Materials

In this study, Scots pine (*Pinus sylvestris* Lipsky), Oriental beech (*Fagus orientalis* Lipsky), Oak (*Quercus petraea* Lieble) and Chestnut (*Castanea sativa* Mill) were used for preparing the specimens. These species are widely utilized in the manufacturing of furniture frames. Wood materials were randomly selected from the commercial suppliers in Karabük, Turkey (Figure 1e, f, g, h, and ı, respectively). The test specimens were selected natural colour uniformity, smoothness of fibers, absence of knots, heart uniformity, absence of reaction wood, and absence of fungal and insect damage. It has been paid attention that the wood material used in experimental studies is not exposed to physical damage, mechanical impacts, or biological damage. Moisture contents (MC) and densities of the wooden materials were tested according to TS 2471 (TSE 1976) and TS 2472 (TSE 1976) standards, respectively. The ovendried density values were 0.50, 0.67, 0.69, and 0.57 g/cm³, for Scots pine, Oriental beech, oak, and chestnut, respectively. Beech dowels, oak dowels, chestnut dowels and Scots pine dowels 8 mm in diameter and 40 mm in length were chosen for this study (Figure 1f, g, h, and ı). Glass-fiber woven fabrics (GFRP) and basalt-fiber woven fabrics (BFRP) having 200 ± 10 g/m² were used. These materials used in the study was obtained by Dost Chemical Industry Raw Material Industry and Trading (Figure 1c and d). Fiber woven fabrics were prepared by cutting to 100 mm in long and 50 mm in width. The dowels were assembled with the polyvinyl acetate (PVAc) adhesive which is commonly used in the wood industry. The glue was applied to the dowel surfaces and dowel holes with an average of 200 ± 10 gr/m² with a brush (Beta Chemical Industry and Trade Inc., Istanbul, Turkey) (Figure 1b).

Figure 1: Materials used in experiments samples

Fiber woven fabrics were fastened with epoxy adhesive and hardener. The Shaped of epoxy resin used in the matrix material was MGS L285 resin and hardener was MGS H285 (Dost Chemical Industry Raw Material Industry and Trading Co., Istanbul Turkey) (Figure 1a). The technical parameters of the two adhesives are shown in Table 1.

Table 1: Technical data and characteristics of the adhesives

Technical Data	Polyvinyl acetate (PVAc-D4)	Epoxy (L285 Resin+ H285 Hardener)
Viscosity (mPas)	19000±5000 at 21 °C	600 - 900 at 25 °C
Working time (min)	35-40 at 21 °C	45-240 at 25 °C
Density (g/cm3)	1.055±3 at 21 °C	1.21 at 25 °C
Solids content (%)	51±2	-
pH	2.5-3.5	-
Main agent/Hardener Ratio (w/w)	100/5	100/50

2.2. Preparation and construction of specimens

The general configuration of the L-shaped specimens is shown in Figure 2. The specimens consisted of two parts, namely, a rail member and a post member. The rail part measured 150 mm long 50 mm width 25 mm thick, whereas the post member measured 125 mm long 50 mm width 25 mm thick. The members were jointed to each other with 2 pieces of 8 mm diameter and 40 mm length beech (*Fagus orientalis* Lipsky), oak (*Quercus petraea* Lieble), Scots pine (*Pinus sylvestris* Lipsky), and chestnut (*Castanea sativa* Mill) dowels with polyvinyl acetate (PVAc) glue. The dowels were produced from wood species measured 100 mm long by 11 mm wide by 11 mm thickness of wood pieces with using a dowel drawing machine. The rail and post members were drilled with a drilling machine. Depth of the dowel holes in both the post and the rail was 21 mm. Then the holes in the member were cleaned with compressed air. The adhesive was spread over the dowel surfaces and dowel holes with approximately

200 g/m[2] calculation. Figure 2 shows a typical placement of dowel centers in the L-shaped joints used in this study. In all samples, a piece of wax paper was included between the two members to prevent any possibility of the members adhesion. Then, areas where the fiber basalt woven fabric and fiber glass woven fabric were to be placed were bonded with an average of 200 ± 10 gr/m^2 with a brush with a blend of epoxy adhesive and hardener. Joint instances were left to dry for two days.

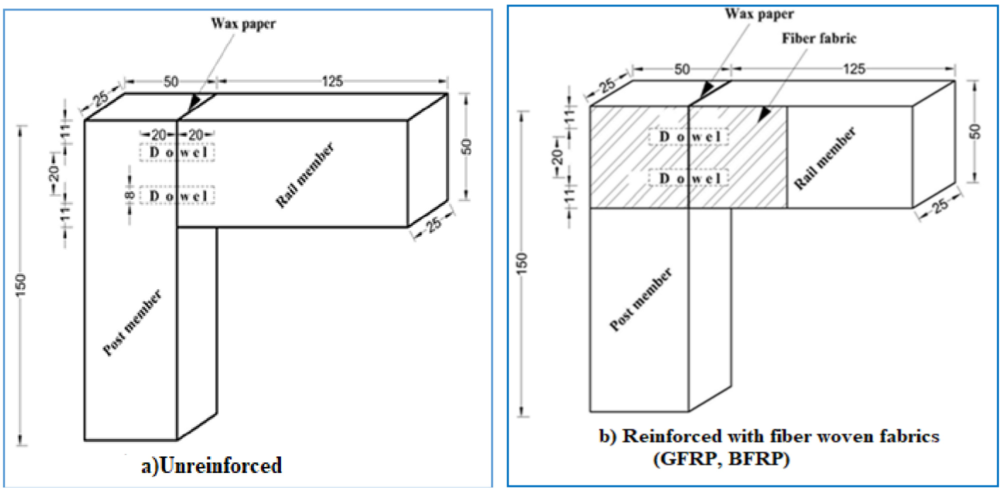


Figure 2: General configuration oh L-shaped joint specimens (dimensions in mm)

According to this, two wood species four wooden dowel species, and two fiber reinforced polymers (BFRP, GFRP, and control), and 5 sample of each material (2 x 4 x 3 x 5) were the variables, totally a number of 120 specimens was constructed in this research. Prior to testing, all samples were conditioned in a humidity chamber controlled at 20 °C ± 2 °C and 65 % ± 5 % relative humidity (RH) for two weeks.

2.3. Methods of Loading and Testing

All of the bending tests of the L-shaped were carried out on a 10-kN Resistance universal-testing machine (SHIMADZU Corp., Sydney, Australia)) in the mechanical test laboratory of Wood Science and Industrial Engineering Department of Karabük University with a 8 mm/min loading rate under static loading. A concentrated load was applied to the rail member of each specimen at a point 100 mm from the front edge of the leg. The moment arm was 100 mm (Figure 3). The loading was continued until a breakage or separation occurred in the specimens. The ultimate loads carried by the joints were recorded with a tolerance of 0.01. The ultimate loads were then converted to corresponding bending moment resistance values by means of the expression. The strength of the joints (modulus of rupture) to bending forces was calculated using the following Eq. (1)

$$M = F \times L \quad (1)$$

where M is the bending moment resistance (N.m), Fmax is the maximum force that caused the destruction of the joint (Max. rupture load) (N), and L is the length of the vertical element of the joint, measured till the loading point and in this experiment this distance was for both corner joints 0.1 (m).

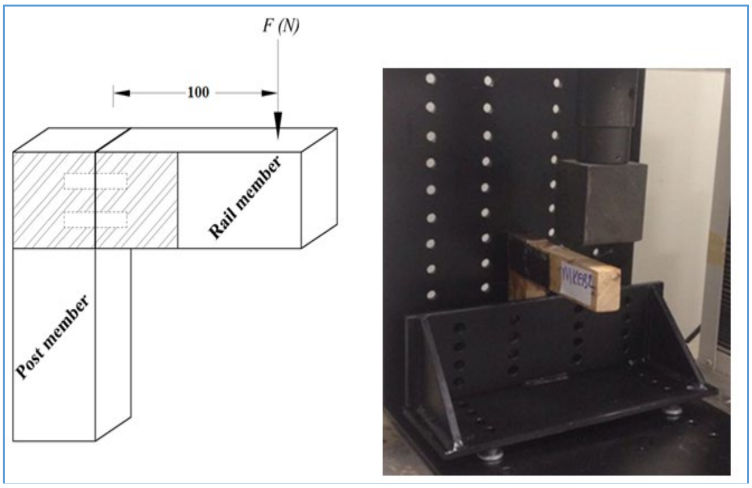


Figure 3: Diagrams showing the bending loading forms and attachments of L-shaped joint specimens to the test rig

A two-way analysis of variance (ANOVA) statistical analysis was used applying the statistical package the statistical package Minitab 18 program. The two-way analysis of variance was carried out on the data at the 0.05 significance level for the individual data to examine the main factors (the wood species of the dowels and reinforced fiber woven fabric types) and their interactions on the bending moment resistance of the joints. It was to be determined by the Tukey test. Tukey test carried out to determine the importance of the differences between the groups

3. Results and Discussion

The mean values bending moment resistance under compression of L-Shaped, two pin dowel joints with their standard deviation and coefficients of variation were presented in Table 2.

Table 2: Mean values of the bending moment resistance of L-shaped joints with their coefficients of variation

Wood Material	Wood species of the dowels	Reinforced fiber woven fabrics (FRP)	Mean (N.m)	SD	COV (%)
Oak	Beech	Control (No-SMT)	44.87	1.56	3.48
		GFRP	59.09	7.37	12.48
		BFRP	83.91	7.05	8.40
	Chestnut	Control (No-SMT)	51.14	4.25	8.32
		GFRP	75.16	6.78	9.02
		BFRP	82.97	7.70	9.28
	Oak	Control (No-SMT)	65.69	7.46	11.36
		GFRP	77.28	9.65	12.49
		BFRP	92.13	9.01	9.78
	Scots pine	Control (No-SMT)	35.75	4.61	12.89
		GFRP	55.94	2.19	3.91
		BFRP	60.10	4.63	7.70

GFRP: Glass fiber woven fabric, BFRP: Basalt fiber woven fabric, SD: Standard devision, COV: Coefficient of variation.

According to multiple comparisons on the bending moment resistance, the highest bending moment resistance value was obtained from jointed with an oak dowel and reinforced with BFRP (92.13 N.m), while the lowest value was acquired in joint with beech dowel and not reinforced (control) (44.87 N.m).

The results of the two-way ANOVA analysis of the wood species of the dowels and reinforced fiber woven fabrics on the bending moment resistance of the L-Shaped, two pin dowel joints under the compression load were given in the Table 3.

Table 3: Summary of the ANOVA results for moment resistance

Source	df	Adj SS	Adj MS	F-Value	P -Value
Wood species of the dowels (A)	3	6209.7	2069.90	39.69	0,000
Reinforced fiber woven fabric Types (B)	2	9318.8	4659.41	89.34	0.000
A×B	6	787.1	131.19	3.10	0.012
Error	54	52.15	2816.3		
Pure Error	2029.2	42.27			
Total	59	18344.8			

R-sq = 84.65%, R-sq (adj)= 82.23% df: Degrees of Freedom.

According to the analysis of variance as presented in Table 3, the effects of the main factors including, the wood species of the dowels (A), the reinforced fiber woven fabric types (B), and interactions of the dowel species and the reinforced fiber woven fabrics (A×B) were found to be statistically significant at the level of 0.05. Tukey test was carried out in order to determine these differences. The bending moment resistance means according to independent effects of test variables were given in Table 4.

Table 4: The results from the Tukey's test for independent effects of test variables

Source		Bending moment Resistance (N.m)	SD	HG
Wood species of the dowels	Oak	78.36	13.83 (17.64)	A
	Chestnut	69.76	15.22 (21.82)	B
	Beech	62.62	17.59 (28.08)	C
	Scots pine	50.59	11.60 (22.94)	C
Reinforced fiber woven fabrics (FRP)	BFRP	79.77	13.92 (17.45)	A
	GFRP	66.87	11.65 (17.42)	B
	Control	49.36	12.06 (24.44)	C

SD: Standart deviation, HG: Homogeneity groups, Values in parentheses are coefficients of variation (CV, %)

For the wood species of the dowels, the oak dowel showed significantly higher the bending moment resistance value than other dowels (Table 4), The bending moment resistance value of oak was approximately 12%, 25% and 55% higher than for joints constructed with chestnut, beech, and Scots pine, respectively, The situation with the species of lumber used for dowels can explain with the structural properties of the materials, The reasons for these may be based on the density of wooden materials, As a general rule, mechanical properties increase as the density of solid wood material increases, There is an increasing-linear relationship between bending strength, modulus of elasticity and shock resistance and density, In previous studies, many researchers have identified this relationship (Bozkurt and Erdin 1995, Bal and Bektaş 2018),

According to fiber woven fabrics, the highest bending moment resistance value were obtained in basalt fiber woven fabric (BFRP) (79.77 N.m), and the lowest was in control samples (49.36 N.m), The mean bending moment resistance of joints with BFRP was 19 % and 62 % higher than joints with GFRP, and not reinforced joints (control), respectively,

Chairman and Kumaresh Babu (2013) obtained that compressive and tensile ultimate strength of BFRP laminates are higher than GFRP laminates of about 43 % and 23 %, respectively, Borri et al, (2013a) investigated flax and basalt FRP strengthened low-grade (bending strength of 18,4 MPa) and high-grade (bending strength of 41,3 MPa) wood beams, The results showed an increase of bending strength of 38,6% and 65,8%, This study concluded that both BFRP and FFRP provided the beams with higher strength and better ductile behaviour, Similar results can be found in another research by Borri et al, (2013b) for flax and basalt FRP, André and Johnsson (2010) applied FFRP and GFRP with similar fabric density (i,e,, 230 g/m^2 for flax and 250 g/m^2 for glass) perpendicular to grain on wood beams, It is reported that the maximum bending load of the entire specimen strengthened with GFRP (45,1 kN) was 23% higher than that one strengthened with FFRP (36,0 kN), McConnell et al. (2015) in their investigations into the reinforcement of wooden beams with BFRP tensile basalt fibres noted an increased load Resistance and rigidity of 28% and 8,7%, respectively, Monaldoa et al. (2019) explained that beams reinforced with BFRP have a bending ultimate load higher of by about 20 % than the case of GFRP,

Wdowiak-Postulak (2021) found that the load carrying resistance of beams reinforced with basalt fibre was higher by, respectively, 13% and 20% than that of reference beams, while their rigidity improved by, respectively, 9,99% and 17,13%. The most popularly used high-strength fibers are carbon fiber, glass fiber, and basalt fiber, In comparison to other fibers, basalt fiber has superior characteristics, that is, high strength to weight ratio, excellent ductility and durability, high thermal resistance, chemical resistance, good corrosion resistance, fire resistance, high temperature resistance, high performance in terms of strength, and cost-effectiveness (Fiore et al, 2011, Wang et al, 2013), as well as the lower potential cost with respect to other fibre-reinforced polymer (FRP) materials (Fiore et al, 2015).

In the literature, it has been reported that in reinforcements made with glass fiber and metal plates, there is usually an increase of over 40% in resistance values (John and Lacroix, 2000; Borri et al. 2013a). Windorski et al. (1997) concluded that the ultimate strength of a three-layer reinforced connection was 33% greater than nonreinforced connection for parallel-to grain loading. Speranzini et al. (2010) investigated solid wood beams externally strengthened with carbon, glass, basalt, hemp and flax FRP under a four-point bending test (the increase of the bending strength was 24.6% and 23.2% for glass and basalt respectively). Dorigato and Pegoretti (2012) compared the quasi static tensile and fatigue properties of epoxy-based laminates reinforced with woven fabrics of basalt, E-glass and carbon fibres with the same areal density (i.e., 200g/m^2). The experimental result showed that the basalt fibres laminates present elastic moduli and strength values higher than those of the corresponding laminates reinforced with glass fibres. Wang et al. (2019) observed that the gradient of the Resistance improvement of BFRP increased, i.e., 14.3%, 50.0% and 107.1% for one, two and three layers of BFRP.

The cost of elements used in traditional reinforcement methods is low compared to that of FRP materials, but in the long run, elements such as bolts, nails, etc, may not be effective on timber, therefore, it is more convenient to use FRP materials instead of traditional reinforcement methods as they require maintenance and repair over time and have low durability.

3.1 Failure modes

After testing, all connections were visually inspected in order to identify the failure mode of the dowels, In the bending moment resistance test of L-Shaped two pin dowel joints construction with Oak wood in not reinforced samples deformations as in Figure 4 were observed, While there was no deformation in the wooden members, bending deformation in the dowel used for the joint was observed, For all of the joint Types, failures initially occurred as opening at the inner face of joints when those joints were subjected to bending moment, The width of the gap between the rail and the post was measured to obtain the degree of decay of the dowel joints, As result, it was seen that the highest rate of the gap was in Oak wood + Chestnut dowel test samples (see Figure 4a4), Oak wood+Oak dowel, Oak dowel+Scots pine dowel, and Oak wood+Beech dowel samples followed respectively (see Figure 4a2, 4a3, and 4a1), respectively.

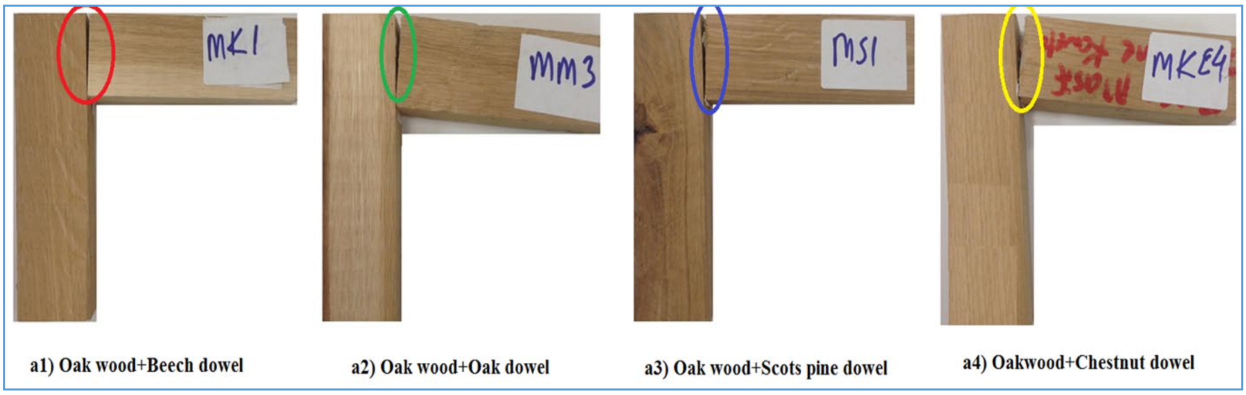


Figure 4: Mode of L-shaped, two pins dowel joint failure not reinforced

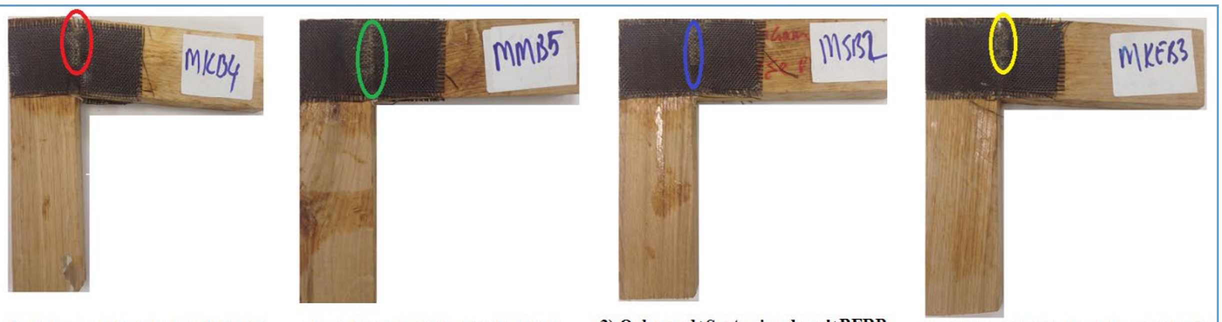
The deformation of dowel joints the reinforced with GFRP strengthened are shown in Figure 5, According to the reinforced joints, glass fiber woven fabric has prevented cracking, It was observed for all of the joint Types, failures not occurred as opening at the inner face of joints when those joints were subjected to bending moment,

The gaps were much shorter than the not reinforced samples, For the samples of the Oak wood+Beech dowel+GFRP, cracks occurred on the inner face of the face members (Figure 5c1), The deformation of dowel joints the reinforced with GFRP strengthened are than not reinforced samples, it is seen that the deformation of the dowel joints reinforced with GFRP is less than the samples in reinforcement.

c1) Oak wood+Beech dowel+GFRP c2) Oak wood+Oak dowel+GFRP c3) Oak wood+Scots pine dowel+GFRP c4) Oak wood+Chestnut dowel+GFRP

Figure 5: Mode of L-shaped, two pin dowel joint failure reinforced with GFRP

The deformation of the L- Shaped two pin dowel joints with inforced by basalt woven fabric under bending strength test is shown in Figure 6, According to test results, the failures that occurred as a split of particleboard in both the face and butt members, In the joints of the test samples reinforced with BFRP, failures have occurred on the outer face of the basalt woven fiber fabric, In all of the samples the beech dowel joints reinforced with BFRP (Figure 6e1), the failures are almost identical, For the samples of constructed with oak wooden, it is seen that the failures occurred as a result of cracking at the junction of the middle of the basalt woven fabric are more in the Oak wood+Beech dowel+BFRP (Figure 6e1) and Oak wood +Chestnut dowel+BFRP (Figure 6e4) samples.



e1) Oak wood+Beech dowel+BFRP e2) Oak wood+ Oak dowel+BFRP e3) Oak wood+Scots pine dowel+BFRP e4) Oak wood+Chestnut dowel+BFRP

Figure 6: Mode of L-shaped, two pin dowel joint failure reinforced with BFRP

4. Conclusions

The bending moment resistance of L-Shaped, two-pin dowel joints constructed four wood species of the dowels and reinforced with basalt fiber woven fabric and glass fiber woven fabric was investigated. Experimental results indicated that traditional glued Oak dowel joints yielded the highest bending moment resistance among Beech dowel, Chestnut dowel and Scots pine dowel joints. Scots pine dowel joints had the lowest bending moment resistance among the joints evaluated. The mean comparison showed that Beech dowel joints could produce a higher bending moment resistance than chestnut dowel joints. The bending moment resistance value of reinforced joints (for GFRP and BFRP joints, respectively) were 35 % and 62 % higher than not reinforced joints. Researchers could be providing a range of optimum values, for the parameters (wood species, four different wood species of the dowels, fiber woven fabric Types) affecting frame furniture joint bending moment resistance and this could be helpful for engineering design of furniture structures, Future studies will have to investigate the bending moment resistance of L-shaped two-pin dowel joints reinforced with different reinforced fiber woven fabric materials.

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ERGONOMIC ANALYSIS OF WORKPLACE FURNITURE IN HOSPITALS: A PUBLIC HOSPITAL EXAMPLE

Tarık Gedik[1]

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Corresponding Author
Tarık Gedik
tarikgedik@duzce.edu.tr

Phone: +90-380-5421137
Fax: +90-380-5421136

Abstract

Within the scope of the study, ergonomic analysis of the furniture elements used by the administrative staff working in Düzce University Research and Application Hospital was made. During the period of the study, 137 employees were reached out of 463 personnel working in the study area, and data were obtained with the help of a questionnaire developed by the researcher in accordance with the purpose of the study. Within the scope of the study, the personnel working in the polyclinics, nurses, midwives, and health officers working in the relevant units were reached. It was determined that the participants reached within the scope of the study were predominantly women, their education level (76.6%) was predominantly at least a bachelor's degree, and about half of them had 4-10 years of experience. As a result of the analyses made, it was concluded that the participants knew the ergonomic working conditions, albeit partially. Participants stated that the equipment they will use in their working areas is sufficient. While the participants positively agree with the adequacy of the cleanliness of the work areas, they agree negatively on the spatial and volumetric sufficiency of the work area. As a result of the analysis, it was determined that the participants were satisfied with the use of the computer desk/desk, study chair and material cupboards they used.

[1] Düzce University, Department of Forest Industry Engineering, Düzce, Turkey

ERGONOMIC ANALYSIS OF WORKPLACE FURNITURE IN HOSPITALS: A PUBLIC HOSPITAL EXAMPLE

Tarık Gedik
tarikgedik@duzce.edu.tr
ORCID : 0000-0001-7372-8295

1. Introduction

Ergonomics: It is a word derived from the ancient Greek terms ergo = work and nomus = science and translated into Turkish as "İş Bilim" by the Turkish Language Association. Studies on ergonomics are also called human-machine relations (Sabancı and Sümer, 2015). The complex relationship between ergonomics and human, machine and job demand can be understood. With the help of ergonomics, the balance between human capacity and work demand in daily life and work activities can be established at the highest rate (Keyserling and Armstrong, 2008).

Ergonomics is considered as an important tool for employees in both the private and public sectors to be motivated to work and to increase their work efficiency. For this reason, the science of ergonomics is dealing with making it easier for employees to work in a more comfortable environment and working towards this (Çeven and Özer, 2013).

Both anatomical structures and physical structures of people differ. For this reason, it is important for performance and productivity to be compatible with the basic characteristics of people and what is expected from them. It should not be forgotten that the work efficiency and performance of the employees will increase with the existence of spaces designed in accordance with the employees and the adaptation of the equipment and equipment used to human characteristics. In the study conducted by Yılmazer and Korkmaz (2012), in which the ergonomic factors affecting the design of the workstations in the offices are examined, it is stated that the highest efficiency can be achieved by establishing the necessary ergonomic standards in the working environments. It has been revealed by the related research that if the working environments are not arranged ergonomically, the work efficiency will be adversely affected, and the employees will experience health problems.

In the study of Babayiğit and Kurt (2013) on health workers, it was stated that ergonomic working environments are also important in addition to paying attention to the principles of posture and posture protection in the formation of pain and diseases related to their profession. Therefore, it has been suggested that an ergonomic patient care system that is compatible with physical, social and psychological characteristics should be created in order to increase the quality of life of patients and healthcare professionals in the hospital environment.

In this study, it is aimed to make an ergonomic analysis of the equipment elements (computer desk/desk, study chair and study cupboard) and working areas used by nurses/nurses, midwives, health officers and cleaners working in Düzce University Research and Application Hospital while working in the hospital environment.

2. Materials and Methods

2.1. Material

The research population consists of administrative staff working at Düzce University (DU) Research and Application Hospital. The study was carried out in May-June 2017. At the time of the study, there were nurses, midwives, health officers and a total of 463 personnel working in the polyclinics working in the units related to the use of the materials examined within the scope of the study (Anonymous, 2017).

Although it was aimed to reach all the administrative staff of the DU Research and Application Hospital within the scope of the study, 137 employees could be reached. It has been assumed that the sample reached with the help of the sample determination formula applied in limited societies is statistically representative of the population with a confidence level of 95% and a margin of error of 7% (Lomeshow et al., 1990). The questionnaires obtained from the sample reached within the scope of the study were statistically evaluated with the help of the SPSS (2003) package program.

2.2. Method

A questionnaire was used to obtain data in the study. The questionnaire form used within the scope of the study was filled by the participants by face-to-face interview method. The questionnaire developed by the researcher (Parlar, 2008; Özmen et al., 2009; Çetin et al., 2015; Gedik et al., 2015) consists of 5 parts. There are 14 questions and 61 judgments in the survey. In the first part of the questionnaire used within the scope of the study, some demographic characteristics of the participants were discussed. In the second part of the questionnaire, it was questioned whether the participants had knowledge about ergonomic working conditions. In the third part of the questionnaire, the objects used in the study areas were questioned by the participants. In the fourth part of the questionnaire, the ergonomic design of the working area was questioned. In the fifth and last part of the questionnaire, the ergonomic features/expectations regarding the ergonomic design of the furniture elements used in the working area, computer desk/desk, study chair and study cupboard were questioned.

3. Results

3.1. Validity and Reliability Analysis

The Cronbach Alpha coefficient was used to determine the reliability of the questionnaires used in the study, and the sampling adequacy measure of the questionnaire and Barlett's sphericity test results were examined to see the results of the validity analysis.

Table 1: Reliability and validity results of the questionnaire used

Working Type	Reliability Result Cronbach Alpha Coefficient	Validity Analysis	
		KMO Value	Barlett Value
Workspace ergonomic design features judgments	0.871	0.827	3290.362
Ergonomic design judgments of the computer desk/desk used in the workplace	0.838		
Ergonomic design judgments of the office chair used in the workplace	0.887		
Ergonomic design judgments of material cupboards used in the workplace	0.893		
All scale result	0.954		

As a result of the evaluations made, the general reliability value (Cronbach Alpha Coefficient) for all data was determined as 0.954 as a result of the reliability analysis of the scale used in the research. Reliability analysis results of each subscale used in the study also ranged between 0.838 and 0.893. In the validity of the scale used, the Kaiser Meyer Olkin (KMO) Sampling Adequacy Measure result was 0.827 and Bartlett's Sphericity test was 3290.362; degrees of freedom were found to be df = 741 (p= 0.000) (Table 1). The findings show that the scale used in the study has a high degree of reliability and does not pose a problem in terms of validity (Özdamar, 2002; Kalaycı, 2009).

Tables and figures should be numbered serially and referred to in the text by number.

3.2. Some Demographic Characteristics of the Participants

It was determined that 62% of the participants working in the DU Research and Application Hospital worked in the inpatient services, 16.1% in the intensive care unit, 12.4% in the emergency room and 9.5% in the polyclinic. It was determined that 94.9% of the participants worked as nurses/nurses in this service, 2.1% as midwives, 1.5% as health officers and 1.5% as cleaners.

82.5% of the participants are female and 17.5% are male. 59.8% of the participants were between the ages of 26-35, 26.3% were younger than 25, and 13.9% were 36 and older. When the education levels of the participants were examined, it was determined that 76.6% of them were undergraduate graduates, 16.1% were high school graduates, 4.4% were graduates, 1.5% were associate degree graduates, and 1.5% were primary school graduates.

When the professional experience of the participants was examined, it was determined that 50.4% had 4-10 years of professional experience, 24.1% had 1-3 years, 19% had 11-15 years, 6.5% had 16 years or more professional experience.

3.3. Analysis of Participants' Information on Ergonomic Working Conditions

In this study, in which the ergonomic working conditions of the participants and the ergonomic design features of the furniture fittings they use were examined, it was first questioned whether the participants had knowledge about ergonomic working conditions. While it was determined that 17.5% of the participants knew what ergonomic working conditions should be, it was determined that 52.6% of them partially knew the ergonomic working conditions and 29.9% of them did not know ergonomic working conditions at all. In the study conducted by Gedik et al. (2015) on Düzce University academic staff, it was determined that 37% of the participating academicians had absolutely no knowledge about ergonomic working conditions in offices and computer use. In the study by Eyi (2020), in which musculoskeletal disorders caused by ergonomic factors in hospitals were examined, it was stated that musculoskeletal disorders and burnout syndrome are two of the most frequently occurring occupational problems in healthcare workers. For this reason, it is thought that it would be beneficial to inform the employees about ergonomic working conditions.

Within the scope of the study, it was determined that 56.2% of the participants wanted to receive information/training about ergonomic working conditions, while 43.8% did not want to receive information/training about ergonomic working conditions.

3.4. Analysis of Objects Used by Participants in their Study Areas

While 76.6% of the participants stated that there were no accessories that would ease their work in their work areas, 23.4% stated that there were accessories that would ease their work in their work areas.

The presence and use of objects in the study areas of the participants are shown in Table 2.

Table 2: Objects found in work areas

Objects	Available (%)	None (%)
Table	94.9	5.1
Chair	95.6	4.4
Height-adjustable swivel office chair	75.2	24.8
Computer	96.4	3.6
Computer table	89.1	10.9
Curtains, blinds to protect from sun and light	73.0	27.0
Bookshelf	19.0	81.0
Cupboard with drawers and shelves	80.3	19.7
Guest couch	34.3	65.7
television, radio	83.9	16.1
Flowers, paintings, etc. objects with a psychological effect	48.9	51.1
Telephone	93.4	6.6
Stand	54.7	45.3

It was stated that objects such as tables, chairs, computers and telephones were found in the study areas of the participants over 90% and were used by the participants. It has been determined that 89% of the participants also have a computer desk in addition to a desk/desk. It was observed that there were no objects with psychological effects such as bookshelves (81%), guest chairs (65.7%), flowers and paintings (51.1%) in the study areas of the participants.

3.5. Analysis of the Ergonomic Design of the Workspace

Within the scope of the study, cluster analysis was used to determine the satisfaction levels of the participants in the ergonomic design of their workspaces. With cluster analysis, meaningful groups or clusters can be formed in the data set that is the subject of the research (Neil, 2002). With cluster analysis, comparison and grouping are made by considering the characteristics of the variables (Kalaycı, 2009).

As a result of the analyses made, the grouping of the research results showing the satisfaction levels of the participants regarding the ergonomic design of the workplaces they use according to their importance levels is shown in Table 3. A statistically significant grouping emerged as 3 groups as a result of the clustering analysis in the data of the satisfaction levels related to the ergonomic design of the workspaces used by the participants ($p<0.05$). The final cluster centres of the 3 groups that emerged were 3.39 for Group 1; It was determined as 3.03 for the 2nd Group and 2.82 for the 3rd Group.

Table 3: Cluster analysis results of participants' satisfaction with their workplace

Judgments	x̄	σ	Cluster	Distance
Working areas are regularly cleaned.	3.45	0.97	1	0.058
There are dirty-clean material areas in the working areas.	3.41	0.98	1	0.021
There are sufficient antiseptic and disinfectant materials in the working areas where necessary.	3.39	1.14	1	0.001
Fire extinguisher systems/tools are sufficient in working areas.	3.31	0.82	1	0.077
There are ideal materials-environments (such as curtains, screens or practice rooms) to ensure privacy in work areas.	3.10	1.02	2	0.074
Communication and information flow can be done smoothly in the working areas.	3.05	0.97	2	0.024
The walls are painted with a calming color paint suitable for the technique.	3.03	1.20	2	0.002
The work area is adequately and properly heated.	3.01	1.14	2	0.013
I know what the dimensions of the workspace should be.	2.94	1.07	2	0.087
Guiding and warning signs are sufficient for work areas.	2.90	1.03	3	0.083
The work area is adequately and appropriately illuminated.	2.84	1.07	3	0.018
The working area is adequately and properly cooled.	2.84	1.13	3	0.017
Private resting areas are sufficient in the working areas.	2.83	1.07	3	0.009
The work area is adequately ventilated.	2.80	1.14	3	0.016
The workplace has sufficient area and volume.	2.71	0.94	3	0.111

Likert scale: 1 At least or not at all, 2 Little, 3 Undecided, 4 Much, 5 Most
x̄: Arithmetic mean, σ: Standard deviation

In case of satisfaction with the ergonomic design of the working areas used by the participants, it has been determined that the employees are satisfied with the regular cleaning and cleaning of the working areas, the places where the dirty and clean materials are placed separately, the antiseptics and disinfectants necessary for cleaning and hygiene, and the fire extinguishers/systems in the work areas.

It was determined that the participants had problems in terms of the adequacy of the working areas in terms of both area and volume, the insufficient ventilation of the working areas, the lack of private resting places in the work areas, the inability to provide appropriate thermal comfort and insufficient lighting in the work areas, and their satisfaction levels were low. In a study conducted by Çeven and Özer (2013), it was determined that people who work in work environments designed by considering ergonomic working conditions can be better motivated, get less tired, and accordingly, their working performance is higher and they complain less about the discomforts caused by working conditions. . In the study of Gedik et al. (2017), in which the problems experienced by the academic and administrative staff of Düzce University in their office work were analysed, it was determined that the desks used by the participants were not suitable and therefore they experienced discomfort. In addition, it was claimed that the participants also experienced problems due to their computer hardware.

3.6. Analysis of the Ergonomic Design of the Furniture Elements Used by the Participants in Their Work Areas

The furniture used by the participants in the study areas within the scope of the study; used computer desk/desk, used work chair and used drawer cupboards are discussed under 3 sub-headings. The research results showing the ergonomic design satisfaction of the participants for the computer desk/desk they use are shown in Table 4. A statistically significant grouping structure emerged as 3 groups as a result of the clustering analysis in the data of the satisfaction status of the users in the computer desk/desk design used by the participants ($p<0.05$). The final cluster centres of the 3 groups that emerged were 2.94 for Group 1; It was determined as 2.68 for the 2nd Group and 2.49 for the 3rd Group.

Table 4: Cluster analysis results of participants' satisfaction with computer desk/desk design

Judgments	x̄	σ	Cluster	Distance
The computer desk has sufficient weight and rigidity.	3.01	1.08	1	0.071
The height of the computer desk is sufficient and suitable	2.95	1.03	1	0.011
The area of the computer desk is sufficient and convenient	2.93	1.03	1	0.004
The area occupied by the printer does not adversely affect the working conditions.	2.86	1.20	1	0.078
Desk lamp (if equipped) illuminates the work area appropriately	2.68	1.19	2	0.001
There are suitable shelves on the desk where files can be placed.	2.68	1.21	2	0.001
I know what the dimensions of the computer desk should be	2.49	1.05	3	0.000

Likert scale: 1 At least or not at all, 2 Little, 3 Undecided, 4 Much, 5 Most
x̄: Arithmetic mean, σ: Standard deviation

It was determined that the hardness and stability of the computer desk/desk used by the participants met the user expectations well. In addition, the participants claimed that the height of the computer desks/desktops is sufficient for the usage areas. Although the participants stated that they were satisfied with the use of the computer desk/desk, it was observed that they did not know very well what the ideal dimensions of the computer desk/desk should be. In addition, it was determined that the participants were less satisfied with the adequacy of the local lighting in the working areas (with the desk lamp) and the adequacy of the shelves required for the files on the desks.

The results of the research showing the satisfaction levels of the participants with the ergonomic design of the office chair they use are given in Table 5. A statistically significant grouping structure emerged as 3 groups as a result of the cluster analysis in the data of the satisfaction status of the users in the design of the office chair used by the participants ($p<0.05$). The final cluster centres of the 3 groups that emerged were 3.07 for Group 1; It was determined as 2.94 for the 2nd Group and 2.68 for the 3rd Group.

Table 5: Cluster analysis results of participants' work chair use satisfaction

Judgments	x̄	σ	Cluster	Distance
The distance of the chair from the keyboard is sufficient and appropriate.	3.13	1.129	1	0.062
The chair is convenient and has adjustable height.	3.04	1.018	1	0.027
The chair back supports my waist appropriately.	3.04	1.036	1	0.035
The seating surface of the chair has a suitable profile.	3.00	1.137	2	0.062
The chair back has a suitable slope and height for my back.	2.95	.987	2	0.010
There is a suitable clearence volume and footrest that the feet can step on.	2.91	1.188	2	0.029
Chair armrests (if any) have adequate and suitable position.	2.89	1.002	2	0.043
I know what the dimensions of the chair should be.	2.68	1.059	3	0.000

Likert scale: 1 At least or not at all, 2 Little, 3 Undecided, 4 Much, 5 Most
x̄: Arithmetic mean, σ: Standard deviation

It can be said that the general satisfaction of the participants regarding the office chair they use is partially low. It can be said that the participants partially do not know what the ergonomic dimensions of the office chair they use should be.

The results of the research showing the satisfaction of the participants with the ergonomic design of the material cupboards they use are shown in Table 6. A statistically significant grouping structure emerged as 3 groups as a result of the clustering analysis made on the data of the satisfaction status of the users in the design of the material cupboards used by the participants ($p<0.05$). The final cluster centres of the 3 groups that emerged were 2.95 for Group 1; It was determined as 2.78 for the 2nd Group and 2.61 for the 3rd Group.

Table 6: Cluster analysis results of participants' satisfaction with the use of material cupboards

Judgments	x̄	σ	Cluster	Distance
Material cupboard drawers have sufficient volume.	2.99	0.999	1	0.034
The volume of the material cupboards is not large enough to prevent other working areas.	2.99	0.985	1	0.034
The material does not consume much space when the cupboard doors are opened.	2.93	1.119	1	0.018
The edges of the material cupboards are made so as not to damage them.	2.93	1.121	1	0.025
The compartments of the supply cupboards have the appropriate volume to place the medicines.	2.81	1.022	2	0.022
Material cupboards have sufficient area and volume.	2.76	0.990	2	0.022
Material cupboards are suitably illuminated.	2.66	1.005	3	0.045
I know what the dimensions of the material cupboards should be.	2.57	1.007	3	0.045

Likert scale: 1 At least or not at all, 2 Little, 3 Undecided, 4 Much, 5 Most
x̄: Arithmetic mean, σ: Standard deviation

It can be said that the participants do not experience too many problems with the material cupboards they use, since the drawers are of sufficient volume, the dimensions of the material cupboards do not cause any negative effects in the working areas, they do not take up much space when the doors are opened, and the edges are designed in such a way that they do not harm the employees.

It was determined that the participants felt uncomfortable because the material cupboards were not properly and adequately illuminated, and they did not know very well what ergonomic dimensions the material cupboards should be.

In a study conducted by Alp et al. (2012) in a public hospital in the province of Isparta, it was suggested that 96% of the participating healthcare professionals had musculoskeletal problems due to inappropriate working conditions or inappropriate ergonomic designs. In addition, it has been determined that the upper and lower compartments are not ergonomically suitable for the material cupboards used in the study, and although the desks, computer tables and chairs are individually ergonomic, there is no harmony between the chair and the table.

4. Conclusion and Reccommediation

It should not be forgotten that the nurses/nurses, midwives and health officers working in hospital environments spend most of their time at the desk/desk, and the work chairs and the cupboards they use have an important place. Therefore, it should be noted that higher efficiency can be obtained from ergonomically designed reinforcement elements for these users. As a result of the analyses made;

- It can be said that the participants have partial knowledge about ergonomic working conditions. It can be said that it would be beneficial to provide training/information about ergonomic working conditions to the participants.
- It has been determined that 90% of the participants have the objects (table, chair, computer, telephone) they need to carry out their work in their work areas.
- It was determined that the participants were satisfied with the cleanliness and orderliness of the working areas, and the sufficient material required for hygiene. However, it was observed that the participants were not satisfied with the environmental and climatological factors (such as lack of lighting, ventilation, sufficient area, and volume) of the working areas.
- While it can be said that the participants are partially satisfied with the computer desk/desk, work chair and material cupboards they use in their working areas, it has been observed that they do not know what ergonomic dimensions the computer desk/desk they use should be.
- It was determined that the materials cupboards used by the participants were not in sufficient area/volume for them to work comfortably.

It should not be forgotten that the arrangement of the reinforcement elements used from the findings obtained as a result of the analyses, taking into account the ergonomic design principles, will contribute to the higher performance of the employees.

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DETERMINATION OF THERMAL CONDUCTIVITY OF LAMINATED WOOD MATERIALS DEPENDING ON THE LAYER ORIENTATION

Özkan Cırrık[1]

Citation

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Laminated Wood Materials
Plywood
Laminated Veneer Lumber
Thermal Conductivity

Abstract

In this study, it was aimed to determine the thermal conductivity coefficient values of laminated wood materials produced with different layer orientation, according to wood species and adhesive type. For this purpose, 5-layers plywood, laminated veneer lumber (LVL), Kerto-Q-LVL and special type plywood (Q-plywood), which formed three rotary cut veneers in the inner layer parallel to each other, perpendicular to the outer layers, panels were produced. In the production of the panels, poplar (*Populus deltoides*), Scots pine (*Pinus sylvestris* L.) and spruce (*Picea orientalis* L.) were used as a wood species and was used urea formaldehyde (UF) and phenol formaldehyde (PF) as adhesive types. The thermal conductivity coefficient measurements of the panels were carried out according to the ASTM C 518 standard. As a results of the study, the highest thermal conductivity coefficient value was obtained from Q-LVL panels produced using UF adhesive from spruce veneers. The lowest thermal conductivity values were obtained from plywood produced using PF adhesive from spruce veneers.

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Corresponding Author
Özkan Cırrık
ozkan.cirrik@keas.com.tr
Phone: +90-534-5013667
Fax: +90-266-2811259

[1] Kastamonu Entegre Ağaç Sanayi ve Ticaret A.Ş., Balıkesir, Turkey

DETERMINATION OF THERMAL CONDUCTIVITY OF LAMINATED WOOD MATERIALS DEPENDING ON THE LAYER ORIENTATION

Özkan Cırrık
ozkan.cirrik@keas.com.tr
ORCID : 0000-0002-0119-7509

1. Introduction

Wood and wood products have an important place in human life and in the development process of culture since ancient times and today. Molecular, chemical and microscopic properties of wood have enabled it to be used for a wide variety of purposes. In addition to these properties, its fibrous structure has led to its high strength and flexibility in engineering uses. In addition, it has often been the reason for preference in terms of its isolation properties (Öztürk and Arıoğlu, 2006).

Laminated wood materials are obtained by bonding two or more layers and joining them in such a way that the fibre directions of the layers are parallel or perpendicular to each other. If the produced material is curved, the fibre directions of the layers must be applied in parallel. Laminated wood materials, different wood types, variable number of floors, different sizes, shapes, and coat thicknesses can be applied (Şenay, 1996). In the laminated wood material method, longer and wider wood materials can be produced from short and narrow-width wood materials. In addition, the quality properties of the wood product produced are better, since it allows the wood to be used by removing the defects of the material (knots, cracks, wormholes, irrigation, etc.). Due to the use of small-sized wood material, the waste rate in wood material decreases, which has an impact on the cost of the finished product (Perçin et al., 2009). The structure of the wood materials used in the production of laminated wood materials, surface roughness, pressing pressure, pressing time and the technical properties of the adhesive used are effective on the bonding and other mechanical strength properties of the materials (Keskin, 2003).

Thermal conductivity is the flow of thermal energy through a unit thickness of a material under a temperature gradient and expressed by the coefficient of thermal conductivity (Kollman and Cote, 1968). It is a very important parameter in determining heat transfer rate and is required for development of drying models in industrial operations such as adhesive cure rate (Kol et al., 2008). Also, it must be known when choosing the insulation materials to attenuate fluctuation in the outdoor environment which maintains an indoor temperature that is independent of outdoor temperature fluctuations. The materials used for insulation must have good warmth-keeping properties such as lower thermal diffusivity to provide sufficient protection from severe temperature changes (Kawasaki and Kawai, 2006). Wood materials possess a superior thermal conductivity property compared to other building materials which is due to its porous structure of them (Gu and Zink-Sharp, 2005; Kruger and Adriazola, 2010). They are one of the preferred materials in many applications such as construction industry, refrigerators, automobile industry, and in the manufacture of barrels, because of their low thermal conductivity and high resistance (Gu and Zink-Sharp, 2005). Thermal conductivity of wood materials has varied according to wood type, direction of wood fiber, resin type, and additive members used in the manufacture of wood composite panels (Kamke and Zylkowoski, 1989).

This study aimed to investigate the thermal conductivity coefficient values of laminated wood materials produced with different layer orientation, according to wood species and adhesive type. For this purpose, thermal conductivity tests were carried out by producing five-layer panels with 4 different layer orientations.

2. Materials and Methods

2.1. Material

The peeling logs used in this study were obtained from the operating directorates of the General Directorate of Forestry. As wood species, the species commonly used in the laminated wood material industry were selected. Coniferous wood species; Scots pine (*Pinus silvestris*) and Eastern Spruce (*Picea Orientalis*) were selected. In addition, Hybrid Poplar (*Populus deltoides* I-77/51) clone was used in the study as a hardwood wood species in logs.

The rotary cut veneer sheets with dimensions of 2 mm ×50 cm × 50 cm thickness were obtained from freshly cut logs. While the poplar veneers were manufactured from freshly cut logs, Scots pine and spruce logs were steamed for 12 h before veneer production. The horizontal opening between knife and nose bar was 85% of the veneer thickness, and the vertical opening was 0.5 mm in rotary cutting process.

The veneers were then dried to 6–8% moisture content with a veneer dryer. Two types of resins were used as adhesive, urea formaldehyde (UF) and phenol formaldehyde (PF) resins with 65% solid content. UF resin solutions used in the laminated wood materials manufacturing were composed of 100 parts UF resin, 30 parts wheat flour and 10 parts NH_4Cl (with 15% concentration) as hardener, by weight. PF was used directly for the laminated wood materials. The adhesive was applied at a rate of 160g per cubic meter to the single surfaces of veneers with a four-roller glue spreader. The bonded veneer sheets were formed in 5 layers using 4 different layer orientations. The panel drafts formed are given in Figure 1.

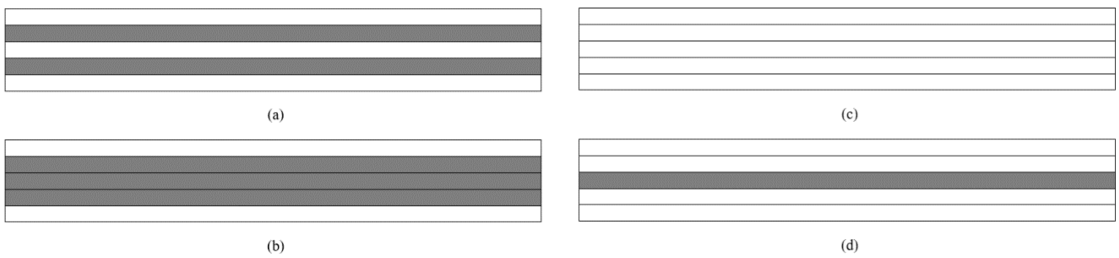

Figure 1: (a) 5-layer plywood, (b) 5-layer plywood with middle layers bonded in parallel (Q-Plywood), (c) 5-layer LVL, (d) 5-layer KERTO Q-LVL, the dark coloured layers were placed perpendicular to the fibres

Hot pressing time and temperature were applied as 10 minutes, 110°C for UF resin and 140°C for PF resin while press pressure was 12 kg/cm^2. Two replicate plywood panels were manufactured for each test group. Test samples were conditioned to achieve equilibrium moisture content at 20°C temperature and 65% relative humidity prior to testing.

The thermal conductivity of laminated wood materials was determined according to ASTM C 518 (2004). Two specimens with the dimensions of 300×300×2 mm was used for each group. The Lasercomp Fox-314 Heat Flow Meter shown in Figure 2 was used for the determination of thermal conductivity.

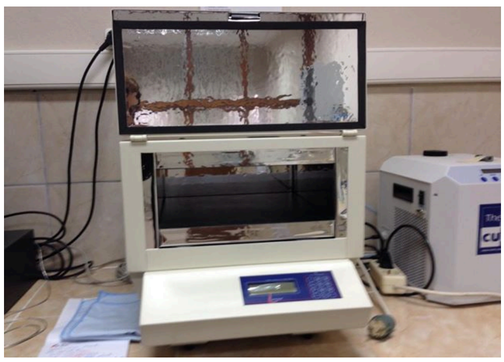

Figure 2: Lasercomp Fox-314 heat flow meter

3. Results and Discussion

The thermal conductivity coefficient values of the produced panels are given in Table 1 for each laminated wood material according to the wood species and adhesive type.

Table 1: Average values of thermal conductivity coefficient of the produced panels

Wood Species	Adhesive Type	Panel Type	Thermal Conductivity Coefficient (W/mK)
Scots pine	UF	Plywood Q-Plywood LVL Q-LVL	0.1017 0.09594 0.09611 0.09123
	PF	Plywood Q-Plywood LVL Q-LVL	0.08778 0.09171 0.1020 0.1034
Spruce	UF	Plywood Q-Plywood LVL Q-LVL	0.09388 0.09621 0.09249 0.1093
	PF	Plywood Q-Plywood LVL Q-LVL	0.07277 0.09738 0.09629 0.09419
Poplar	UF	Plywood Q-Plywood LVL Q-LVL	0.09135 0.09777 0.09817 0.09218
	PF	Plywood Q-Plywood LVL Q-LVL	0.09606 0.09148 0.08896 0.09371

As seen in Table 1, the highest thermal conductivity coefficient value was obtained from Q-LVL panels produced from spruce veneers using UF adhesive, while the lowest thermal conductivity values were obtained from plywood panels produced from spruce veneers using PF adhesive. The effects of layer orientation and adhesive type on thermal conductivity coefficient values differ according to wood species. Differences were observed between the thermal conductivity coefficient values of the panels in the same layer orientation produced with UF and PF adhesive.

The thermal conductivity coefficient values of the panels produced by using UF and PF adhesives within the scope of the study; depending on the layer orientation, the wood species obtained, and the type of adhesive used. The thermal conductivity coefficient changes of the produced panels are shown in Figure 3.

When the effect of the layer orientation on the thermal conductivity coefficient of the panels was examined, it was seen that the thermal conductivity coefficient values differed according to the adhesive type and wood species. Plywood for scots pine, Q-LVL for spruce; LVL for poplar gave the highest thermal conductivity values in UF adhesive. The lowest values were found in Q-LVL for Scots pine, in LVL for spruce, and in plywood sheets for poplar. Q-LVL for Scots pine, Q-Plywood for spruce, plywood for poplar gave the highest thermal conductivity values in PF adhesive. The lowest values were found in plywood for scots pine and spruce in LVL sheets for poplar. The differences between the thermal conductivity coefficient values of the groups are quite small. The ability to transmit heat in wood material varies according to the wood species and the direction of the fibres in the same wood, as well as directly related to the anatomical structure of the wood material (Berkel, 1970). In addition, it has been emphasized in many studies that the thermal conductivity value varies according to the tree species (Kol and Sefil, 2011; Rice and Shepard, 2004). In addition, density, moisture, amount of extractive material, fibre direction, structural irregularities such as knots, cracks and fibre angle, and temperature can be considered as effective the factors of the thermal conductivity of wood (Simpson and Tenwolde, 2007).

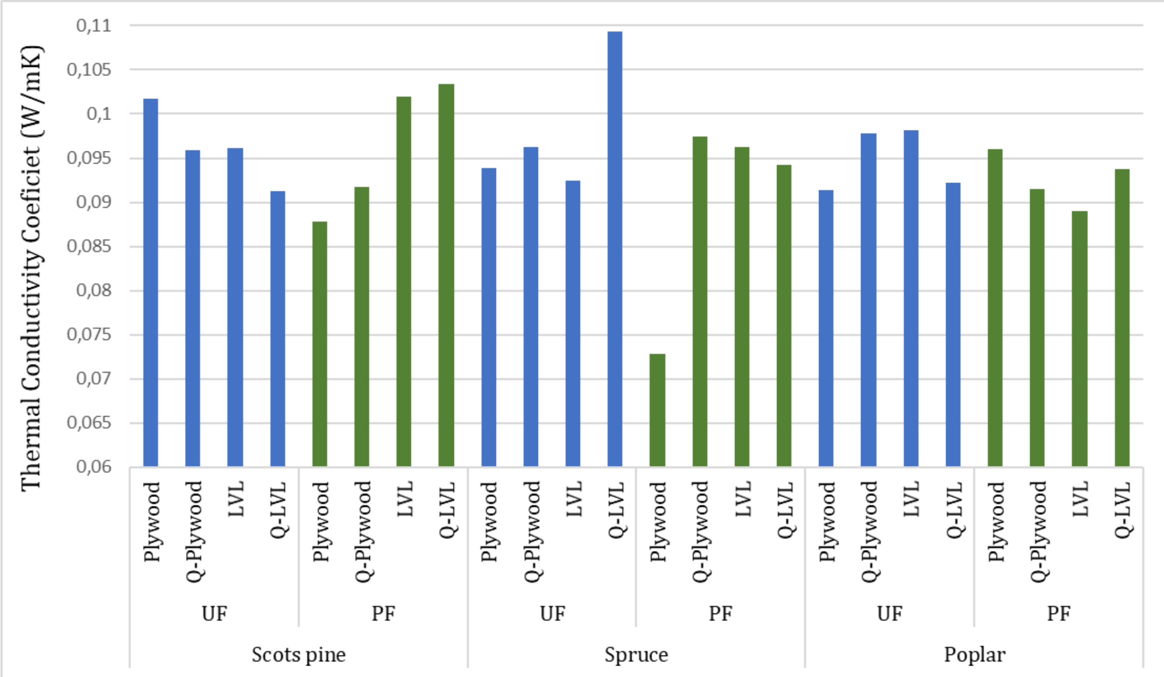

Figure 3: Thermal conductivity coefficient changes of laminated wood materials

When the effect of wood species used in production on the thermal conductivity coefficient of the panels is examined, (the highest thermal conductivity coefficient values were obtained in Scotch pine for plywood panels in UF adhesive, in Poplar for Q-Plywood and LVL, in spruce for Q-LVL. The lowest values were found in poplar for plywood; Scotch pine for Q-Plywood and Q-LVL, in spruce for LVL. The highest values in PF adhesive were obtained in poplar for plywood panels in spruce for Q-Plywood, in scots pine for LVL and Q-LVL. The lowest values were found in spruce for plywood; Q-Plywood in poplar for LVL, Q-LVL. It has been emphasized in many studies that the thermal conductivity coefficient value varies according to the wood species (Kol and Sefil, 2011; Rice and Shepard, 2004). Thermal conductivity in sheet products made of wood material; wood panels produced with various binders and fillers and additives added to them differ according to the type of binder and additives (Kamke and Zylkowoski, 1989). Demirkır (2012) stated that factors such as wood type, coating drying temperature, peeling temperature, type of glue used in production affect the thermal conductivity values of plywood.

When the effect of adhesive types used in production on the thermal conductivity coefficient of the panels was examined, the thermal conductivity coefficient values of the panels produced with UF adhesive were found to be higher than those of PF adhesive. The equilibrium moisture content of the panels produced with UF adhesive was found to be higher than that of PF adhesive. In the literature, it has been stated in the literature that thermal conductivity increases with the increase in humidity due to the high conductivity of water (Gu and Hunt, 2007; Kurt et al., 2008; Kol, 2009; Kol and Sefil, 2011). Kol et al. (2008), it was determined that the type of glue has a significant effect on the thermal conductivity values of laminated panels produced using UF and PF adhesives.

When the thermal conductivity coefficients of the produced experimental groups were compared with the thermal conductivity coefficients of some wood-based panels, results were consistent with the literature (Kawasaki and Kawai, 2006).

4. Conclusions

1. The highest thermal conductivity coefficient value was obtained from Q-LVL panels produced using UF adhesive from spruce veneers.

2. The lowest thermal conductivity values were obtained from plywood produced using PF adhesive from spruce veneers.

3. The effect of layer orientation and adhesive type on thermal conductivity coefficient values differ according to wood species. Differences were observed between the thermal conductivity coefficient values of the panels in the same layer orientation produced with UF and PF adhesives.

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AN EVALUATION ON THE HISTORY OF FURNITURE AFTER THE INDUSTRIAL REVOLUTION

Okşan Ölmez[1], *İnci Versan Alkan*[2]

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Corresponding Author

Okşan Ölmez
oksanolmez@trakya.edu.tr

Phone: +90-284-2250117
Fax: +90-284-2256995

Abstract

Since prehistoric times, people have built shelters to survive and live in a sheltered place. In the built shelters, raised areas according to the needs, protrusions or hollows formed on the walls, softened and ovalized parts of natural materials; although we have not reached the present and do not see a precise example, it can be thought that it includes the first approaches that reveal the concept of furniture.

Furniture, which was originally produced to provide the needs to facilitate the living conditions, has become reflective of the socio-economic, socio-political, and socio-cultural situation of the period and its purpose produced by these furniture shows in connection with concepts such as showing status, power, wealth, divinity. With the development of tools and machines, furniture styles and models have changed with the increasing needs, and the artisans started to reflect their style on the furniture by being influenced by the environment and the period they live in.

After the industrial revolution, the use of furniture has become widespread, not only its handmade production but also with its ability to produce in factories and with providing cost less; diversified in form, function and material.

In this work, the movements emerging as reflections of changing thought systems with the development of furniture in history and the beginning of the industrial revolution and furniture styles and types that will change with the movements were examined.

As a result of the works, we see that the change the materials, design and usage areas by time. Movements have a major role in the development of the material by enabling the use of materials in different ways with the returns of the period they were adopted. As the period progresses, thanks to these materials whose usage areas have increased, a furniture specific to each period has been produced.

[1] Trakya University, Department of Architecture (M.Sc. Student), Edirne, Turkey
[2] Trakya University, Department of Interior Architecture, Edirne, Turkey

AN EVALUATION ON THE HISTORY OF FURNITURE AFTER THE INDUSTRIAL REVOLUTION

Okşan Ölmez
oksanolmez@trakya.edu.tr
ORCID: 0000-0001-8942-9062

İnci Versan Alkan
incialkan@trakya.edu.tr
ORCID: 0000-0001-9130-1009

1. Introduction

The concept of furniture, which first emerged by processing materials that exist in nature in order to provide the needs, has taken on the purpose of showing social status and gaining prestige as well as providing the needs since ancient times. The unique social order, social, cultural, technological developments, and architectural styles of each period have affected the furniture design. Furniture manufacturers, on the other hand, showed their unique aesthetic, skill, and thinking concepts in furniture. People see designs of chair legs that are likened to the feet of animals in antiquity. Thrones were used to emphasize the greatness, wealth, or power of kings. In the middle ages, the beliefs of the societies were effective in designs. Although there is a great interest in the ancient period that came with the Renaissance, each country has developed different styles according to its regional characteristics. With new and improved hand tools, it became easier to shape furniture. A veneer-cutting machine was found and new furniture examples were produced.

For this study, a literature review on the history of furniture was made. The purpose of this study is to contribute to the literature.

2. Materials and Methods

For the research, articles, theses, and books on furniture history were searched. The furniture produced in the period from the first age to the present and the sociological, cultural, and economic events of the periods, as well as the new usage and production methods and new materials in each period, were examined. Thus, with the data obtained from this research, it was investigated how the furniture produced in the past affected the furniture produced in the next period.

Theses, articles, and books have been accessed online. Besides, antique furniture pages were searched on the internet, and details such as furniture belonging to the past periods and the dimensions of these furniture, construction techniques, and years of construction were found on these pages.

3. Industrial Revolution and Aftermath

The "Industrial Age" began in 1765 when James Watt discovered the steam engine. As a result of this invention of Watts, mechanization has created great changes in subjects such as iron, steel processing, and coal extraction. With these changes, many new design studies have emerged. The cities, which grow with railways, hotels, canals, steel high-rise buildings, have led to the emergence of new architectural designs. (Kucukerman, 1996) The Industrial Revolution, which first emerged in England at the end of the 18th century and the beginning of the 19th century, spread to the other European countries, including Netherlands and France, and affected the whole world, along with the development of technology, industrial production, and transportation facilities, brought about radical changes in every field. Another issue that affects the design is the changes that occur in the social structure along with industrialization. With the mechanization that developed in parallel with industrialization, not only the production methods but also the products themselves have changed. The 19th century has been the age of engineers. The Pacific Railway in 1869, the first electric car in 1874, the lamp and microphone in 1875, the sewing machine in 1851, and the telephone in 1876 were invented. In the same period, swivel chairs, adjustable chairs, and other patented furniture started to be used in offices of doctors, hairdressers in Europe. In England, the homeland of the industrial revolution, foldable chairs were produced to save space. (Erdem,2007) For many years, furniture has been used to show people's status in society. Although the approach was the same in this period, the approach of designing to bring practical solutions to the daily problems of the middle class was developed. Therefore, furniture manufacturers, which were expected to satisfy large masses of consumers, had to think about the economic factors. Fine workmanship has been replaced by cheaper technologies. Imitations of valuable materials have appeared. And comfort, durability, and functionality are among the required features. The concern for the furniture to adapt to its environment and to appreciate its design visually continues. The transition from handicrafts to industrialization has led to the emergence of new trends shown in Figure 1.

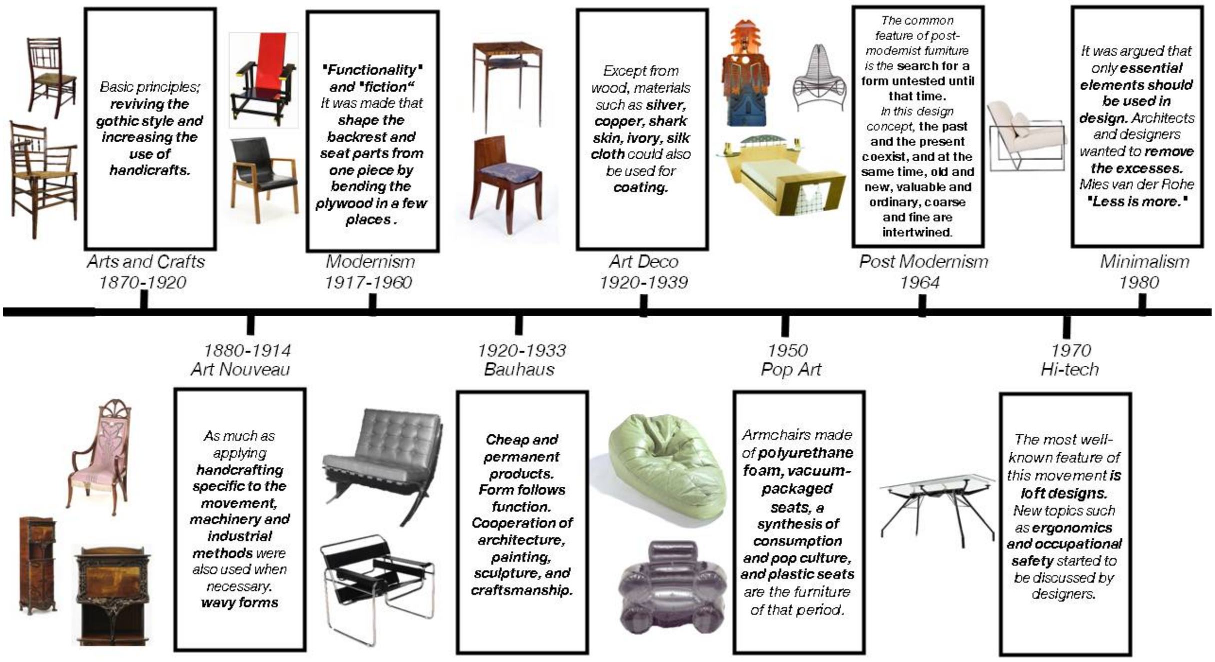

Figure 1: Furnitures and movements after the industrial revolution

3.1. Arts and Crafts

It was common between 1870 and 1920. The name spread with the ideas of *John Ruskin.* William Morris and his friends started practicing. Basic principles were reviving the gothic style and increasing the use of handicrafts.

A system of thinking that aimed to create "original works" free from imitation by working on objects of daily use existed at the basis of the formation. Graphics, fabric, pattern, wallpaper, ceramics, and furniture design constituted an important part of their fields of interest. Mostly solid wood - especially oak was used. Matte varnishes that highlight the grain of the tree were preferred. Furniture was reminiscent of village furniture by type. Japanese design influences could also be seen in many examples. Furniture was created from flat, plain-surfaced tables. The framed system was used mostly in the construction of the tables. Flat rectangular railings or cages were placed in the appropriate areas (seat edges, sides of cabinets, etc.). Small cute patterns made with a small number of carving or inlay methods could decorate surfaces. These patterns were usually composed of stylized natural organisms. Sometimes the entire surface would be covered with a texture. Gothic decorative items were used a lot. Embossed or enameled metal plates placed on surfaces were produced with extremely good workmanship. At the same time, molding techniques were competently used in complementary items such as handles and hinges, which were seen as decorative elements (Boyla, 2012).

Figure 2: William Morris design arts and crafts chair example (Web-1)

The chair in Figure 2 is an original example of an English antique Sussex chair. It is made of alder and beech wood. The seating area is woven from the original sea meadow. Designed by William Morris, this chair has survived from 1870-5. Its height is 91 cm (35.83 '), its width is 54 cm (21.26'), its depth is 45 cm (17.72 inches) and its seat height is 45 cm.

Figure 3: William Morris design arts and crafts chair example (Web-2).

In Figure 3, an example of an arts and crafts movement chair:67 cm high, 35 cm wide, 30 cm deep. It is dated to 1895.

3.2. Art Nouveau

The Art Nouveau was a movement that objected to the imitative understanding of the art of the period and aimed to try new methods and forms. This movement, which started to appear at the end of the 1880s, was again created by arts and crafts movement designers. It has been called by different names in countries: Art Nouveau emphasizing innovation in French, "Liberty Style and Stile Liberte" emphasizing freedom in English and Italian, "Modernista" meaning modernism in Spanish, and "Jugend Style" meaning youth in German. Products on daily use items and building designs were produced. Like Arts and Crafts designs, as much as applying specific handcrafting to the movement, machinery, and industrial methods were also used when it is necessary.

Figure 4: Art Nouveau furniture example (Date: 1900s) (Designer: Majorelle, Louis) (Web-3), Art Nouveau chair example (Date: 1899-1900) (Web-4).

The designer of this chair example shown in Figure 4 is Majorelle, Louis. It is made of walnut wood. Its technique is carving. The back and seat of the chair are embroidered. The fabric is satin and it has fringes. Cabinet maker Louis Majorelle was one of the most influential designers of the Art Nouveau movement. He studied as a painter. At first, he continued to make furniture in the popular Rococo Revival style, but in the 1890s he came under the influence of the Nancy School, created by Emile Gallé, an Art Nouveau glass artist and furniture designer. He began to design furniture pieces - like this armchair - decorated with carving and intarsia, using natural floral motifs and forms. He used plant forms as inspiration but interpreted them as semi-abstract motifs. The silk upholstery on this chair he produced shows how he uses nature as inspiration, not as a direct model.

The main features of this movement are that interest in Japanese art and medieval life, there were designs inspired by nature, organic forms, symbolic approaches, the basic line is the wavy forms. Usually, pastel shades are used.

The designs are inspired by the curves of the branches, the shapes of the leaves, the shapes of the flowers (especially tulips, lilies, water lilies), and peacock figures. By bringing different textures side by side, a colourful effect is created in the space. And one of the important features of this movement is that the furniture is designed in a way that includes integrity with space. A texture found in the furniture can also be used on the ceiling or wall. Not only in furniture, but also in furniture and space, there is an understanding of creating a unity of language and creating a team. Sometimes, furniture can be used as a space divider to separate the space into parts.

Figure 5: An example of art nouveau furniture used as a separator (Web-5).

Figure 5 shows an example that is a part of the panel from the music room. This type furniture which was made of walnut wood, and various woods were applied to the panel by inlay method on this panel. At the top, 'Sainte Odile, patronne de l'Alsace' was written, and there are human figures and nature figures. It was built around the early 1900s. Its designer was Carl Spindler. Used trees are walnut, pear tree, maple, plane tree and, oak. It is 189.1 cm high, 146.8 cm wide and, 67.3 cm deep.

Figure 6: Art Nouveau furniture design (Web-6).

Furniture can have various uses as a function. For example, in the example we saw here, we come across both a seating element and a decorative shelf. These features show that the movement gives importance to both functionality and spatial integrity.

In wooden furniture, the Thonet technique is used, which allows the beech wood to be softened and bent with water vapor to obtain legs in different forms and curved skeletons without using nails. Apart from this technique, folds could be achieved by adding short pieces of wood together. In many cases, design studies could be made for forms that did not fit the properties of the wood. And some designers were able to use metal pipes to get these forms. Water waves, plants, animals, and human figures can be found on the furniture, which is the art of carving made with the natural colors of the trees without using paint by cutting and placing wooden coatings in different colors with handcrafting tools. At the same time, meaningful words and verses can take their place on these surfaces. Relief is obtained by carving solid wooden surfaces. As seen in Rococo, wood and metal can be used together.

3.3. Modernism

The intellectuals and designers met around the magazine "De Stijl" published in Rotterdam, the Netherlands in 1917, close to the end of the First World War, demand that the advancing technology be used to create an egalitarian new world. Meanwhile, people have become impoverished and the countries have been destroyed. De Stijl group progressed based on the principles of science, rationality, and social equality and argued that these principles could be effective in all areas of art and design. The modernist movement began to emerge slowly in the middle of the 19th century. This understanding, which attaches importance to functionality and simplicity, aims to make accessible designs. The importance they attach to simplicity can be understood from Adolf Loos' saying "Ornament is crime"

"In the De Stijl movement, which aims to get rid of individual consciousness and bring it to social consciousness, basic geometric shapes such as round, square, rectangular and yellow, blue, red were preferred. Doesburg "Get rid of nature from external appearances, the main structure will remain." He said. "De Stijl" artists believed that an art that is not based on the public cannot come into existence. Doesburg, in an article he wrote in De Stijl magazine, said, "We should understand that art and life are not separate fields." (Ipsiroglu, 1993).

Figure 7: Gerrit Rietveld, red and blue, 1918 (Charlotte and Fiell, 2012) and red and blue table (Web-7).

As shown in Figure 7, the chair produced in 1918 was made of plywood and solid wood pieces. The structural system was painted black, the parts were joined at right angles and highlighted with cross-connections. The seat is blue and the back is red. The ends of the pieces are yellow. Each piece was highlighted in this way. It was reflected that each piece was accepted separately and formed the whole. Connections between parts are made with screws and bolts. Simplicity, basic colors, and universality were important for De Stijl artists.

The 'Red and Blue Table' is a parallel work with Rietveld's earlier red-blue chair. Horizontal and vertical surfaces painted in red, blue, black, white, and yellow are seen. Rietveld used De Stijl forms also at this table. The table designed for the Schroder House has the asymmetrical style of the house. This style is distinct from the modernist architecture of the 1920s (Duncan, Alashair, 1998).

Figure 8: Modernism chair example (Web-8).

In the 1930s, it is seen that the hard lines of modernist furniture started to soften. Designers like Alvar Aalto were experimenting with plywood or laminated wood. In the United States, Charles Eames and Eero Saarinen, who were lecturers, tried to design furniture which compatible with the human body with plywood between 1937-1939. These two designers were able to shape the backrest and seat parts from one piece by bending the plywood in a few places, and they also influenced the designers who came after them. Designers working on designs that are more compatible with the human body emphasized the necessity of stylization in design, taking into account the spiritual nature of the person. "Functionality" and "fiction" were prioritized as the basic elements in shaping the design and its content was enriched.

3.3.1.Bauhaus

In the same period, the Bauhaus school, which will continue its activity from 1919 to 1933, was opened in Germany. The Bauhaus was started by architect Walter Gropius. This school, which gives examples of modern furniture, has created new trends in the fields of architecture, design, and art by influencing 20th-century design. It brought together the architects and artists of the period in which it was founded, and it is seen that it is not only an educational institution but also a production center and a place where all these are discussed. In 1925, it moved to its new campus in Dessau and tried to be more involved with industrial institutions. During this period, former students have been assigned to teaching positions, and new architects and designer students are trying innovative design practices together. Marcel Breuer started to produce furniture with metal pipes in this period.

The main features of this movement are that a new architectural era started, functionality, cheap and permanent products, the cooperation of architecture, painting, sculpture, and craftsmanship, form follows function, new materials, and techniques, a bond between materials, colors, form, and technology. And Walter Gropius defined the artist as the supreme of the craftsman.

Figure 9: Marcel Bruer - "Wassily chair" (Web-9).

"The Wassily chair, which was inspired by the handlebar of the bicycle, was made of canvas, the seat; backrest and armrest parts were connected to a system consisting of bent pipes. In addition to this 1925 chair, Breuer had designed another chair with tubular legs that supported the seat from the front and turned back on the floor. The first of the chairs with similar legs was conceived by the Dutchman Mart Stam (1899-1986) and inspired one of the Bauhaus teachers, Ludvig Mies van der Rohe (1886-1969). Thus, these three console chairs, which have a similar appearance with small differences, have become a symbol of the period. Among the furniture, which could be made with plumbing pipes first, the ones belonging to Stam and Breuer were later manufactured by the Thonet company. In these years, Breuer used the pipe structural system, such as table, cabinet, etc. he designed other furniture." (Boyla, 2012).

Figure 10: Barcelona chair (Web-10).

Another important Bauhaus furniture is the Barcelona chair designed by van der Rohe in 1929. He designed this chair for the Spanish King, who visited the German pavilion design of him at the Barcelona Fair that he attended that year. This chair was a more ergonomic design that was more compatible with the human body than previous modernist designs. The feet were steel llama, the seat and backrest were leather- covered.

Figure 11: Erich Dieckmann chair - Date: 1926 (Web-10).

Bauhaus was not the only design school exploring these radical ideas, but the most famous. Erich Dieckmann, who designed the chair in Figure 11, was a student at the Bauhaus between 1921 and 1925, and Marcel Breuer can be seen at the intersection of the lines and parts on the chair. In 1925 the Bauhaus moved from Weimar to Dessau, but Dieckmann remained in Weimar and headed the furniture workshop in the renamed Bauhochschule. And the chair in Figure 11 was designed during this period.

3.4. Art Deco

The Decoration Artists Association, founded in Paris at the beginning of the 20th century, was striving for France to regain its former influence in the field of interior architecture and furniture. While there were ideas to exhibit new designs in Paris in 1915, the exhibition was held in 1925 under the effect of the war that broke out. The source of the name Art Deco is "International Decorative Arts and Contemporary Industry Exhibition". Formally, Art Deco can be examined in two different periods. In the period until the 1929 depression, furniture made of precious materials with careful workmanship and a decorative aspect stood out. Traces of various palace styles could be seen on the furniture.

In the 1930s, the effects of the modernist view prevailed and the furniture was simplified again. The center of the Art Deco movement has shifted from France to America. The designers who adopted this trend were applying the traditional techniques used by the old palace furniture designers in their designs. One of the important things in their design is the textures of the trees. The decoration of the surfaces with the marquetry technique became common again. Coverings were made with roots, knotty branches, or sections obtained from the trunk where the patterns are evident. Especially before the 1930s, they were working with tropical trees such as mahogany, rosewood, African olive, and ebony. The colors of the trees were used to create contrast. Except for wood, materials such as silver, copper, shark skin, ivory, silk cloth could also be used for coating (Boyla,2012).

Figure 12: Spider Table and Art Deco furniture examples, design by Ruhlmann, Emile Jacques (Web-10).

Spider Table was created in 1929 by Ruhlmann, Emile Jacques as shown in Figure 12. It is made of ebony wood and has an ivory inlay placed in a circle in the center of the square table. Feet are silver plated and have brass connections. The tabletop is square, the bottom shelf is circular. Height: 80.7 cm, Width: 60 cm top, Depth: 60 cm top, Diameter: 19 cm.

3.5. Pop Art

Pop art movement developed in post-war America. Andy Warhol is the best-known representative of this movement. The issues dealt with by this movement; industrial classical objects used in daily life, popular events experienced, people of public interest. It was intended to show the topics as they are, without adding comments. Warhol, a graphic designer, was making his paintings to copy them. This meant that he created industrial products more than works of art. With this movement reflected in furniture design, the use of plastic materials in design has become widespread. New designs were made without considering the modernist principles. In the 1950s, pop art aimed to reflect the value judgments of the people in a realistic way. In the 1960s, colorful, fun, toy-like types of furniture were designed and items reminiscent of popular events of the period were used for design purposes.

Figure 13: Sacco chair and blow (Web-10).

In the 1950s, designers were designing furniture for important Italian companies such as Zanotta, Cassino, Capellini, Molteni. Armchairs made of polyurethane foam, vacuum-packaged seats, a synthesis of consumption and pop culture, and plastic seats were the furniture of that period. In addition, furniture made of colored and patterned cardboard that can be folded and carried like a box was also being tried. Furniture with features such as portability or puffing could be found. At that time, the rivalry between America and the Soviets, space travels, young people's search for a new life, the use of atomic energy were movement issues, and accordingly, the furniture designed with the influence of the imagination and space films were in fashion.

3.6. Hi-Tech

Towards the end of the 1970s, new life values emerged with the acceptance of technology as reliable. New topics such as ergonomics and occupational safety started to be discussed by designers. Designs were for especially the elderly, disabled people, and children. The most well-known feature of this movement is loft designs. The designs, which emerged in a more refined form compared to the first examples made in the 1970s, started to be produced by the most important representatives of the movement such as Rodney Kinsman, Michael Hopkins, and Richard Rogers. Among the furniture designs of the period dominated by engineering, Norman Foster's table with a glass top, which was designed in 1988, represented an advanced fictional understanding. Despite the flamboyant emergence of postmodernism, some designers continued to work close to Hi-Tech in the 1980s.

3.7. Post Modernism

The post-modernism was first introduced in the 1960s by the critic Nicolaus Pevsner, who believed that "architecture moved away from modernism and assumed a more emotional, formalist, symbolist and illogical identity." The first strong protests against Modernism in America came from architect Robert Venturi (1925-) with the books of

"Complexities and Contradictions in Modern Architecture" (1966) and

"Learning from Las Vegas" (1971).

In the first book, the author argued that concessions should be made on the rational principles accepted in architecture, and the necessity of some distortions, ambiguities, and hybrid styles. In his second book, the importance of the likes of the man in the street was emphasized. Robert Venturi was already practicing his thoughts in the house he had built for his mother in 1962. One of the young architects of the period, Michael Graves' Portland Building in Oregon caught attention in 1980. The AT&T building of Philip Johnson, who worked with Mies van der Rohe for a long time and was a successful practitioner of the modernist view, was built between 1978 and 1982 in New York, with its triangular pediments, proving that Postmodernism has now settled in architecture. The buildings were no less functional than before, but they also contained decorative elements (Boyla, 2012).

Architects of this period were also furniture designers. The common feature of post-modernist furniture was the search for a form of untested until that time. There were designers who both worked with the latest technology and materials, preferred handcrafts, and used both at the same time.

Figure 14: Charles Moore house (Rayn, 2012).

For example, Charles Moore's furniture contained very complex spaces with toy-like figures and structures in layers that developed from the surface to the inside shown in Figure 14. These places could remind you of ancient cities or a modern village. Handwork was inevitable in such a design. The material used was "Formica Colorcore", a synthetic product of the advanced technology of the 1980s. In this design concept, the past and the present coexist, and at the same time, old and new, valuable and ordinary, coarse and fine are intertwined.

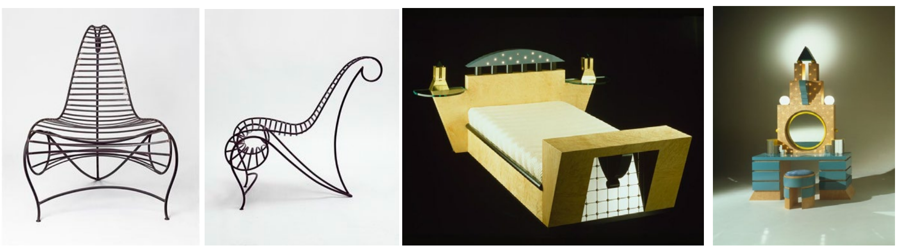

Figure 15: Spine Chair (Web-10) and Michael Graves designs; Stanhope (Web-11), Plaza (Web-12).

Another feature of the furniture was its monumental appearance. Michael Graves' "Plaza" dressing table and "Stanhope" bed, Hans Hollein's "Marilyn" sofa were examples of this type in Figure 15. Portuguese designer Tomas Taveira, on the other hand, designed furniture that was deformed and made meaninglessly decorated to disturb the user. Symbolist approaches are observed in the exaggerations in shaping the furniture and in the ornaments.

3.8. Minimalism

A much simpler design concept emerged in the late 1980s. In the first half of the 20th century, it was argued that only essential elements should be used in the design. Architects and designers who followed the modernist movement in the 1960s also wanted to remove the excesses. Mies van der Rohe "Less is more.", Buckminster Fuller "Doing more with less" and Braun company designer Dieter Rams "Less, but better", said. In the minimalism movement, Japanese architecture, De Stijl movement, and Bauhaus and Ulm schools have great influences.

Besides, with industrialization, people now wanted to move away from poorer quality, more experimental, and flashy furniture. Instead of all these, plain, cheap, and useful ones were preferred. Environmental problems that emerged in the 1990s were too important to ignore. And the understanding of minimalism enabled designers to benefit from natural resources efficiently and without waste by keeping the materials and production works to a minimum.

4. Discussion

Movements in a distinct line that continued for a while in designs were followed by searches and movements in opposite characters. The economic, cultural and political events affected the art and production fields of the period and constantly created new movements. Along with the developing technology with industrialization, products produced with new techniques have emerged. It can be mass-produced and the furniture that can be cost less has become both diversified and accessible to all public. After the Arts and Crafts movement, which aimed to revive the disappearing handicrafts, Art Nouveau emerged, which included machines and industrial methods when necessary, as well as applying handcrafts specific to the Arts and Crafts movement. After the war, modernism, which attaches importance to simplicity, developed and schools such as Bauhaus were opened. Art deco movement, which wanted to continue the traditional techniques used by the old palace furniture makers in their designs, was seen at that time, and then the search for a new life for young people living in the 1950s, comic books and space films, the competition between America and the Soviet, the designs inspired by the news emerged and pop art movement emerged. In this movement, the aim is to convey what is meant without comment. The emergence of concepts such as ergonomics and occupational safety in the 1970s and the technology to prove itself led to the hi-tech movement. And with the search for untested forms, post-modernism emerged, and then the value is given to simplicity and the natural environment increased and the understanding of avoiding pretension. And the minimalism movement was dominated by the understanding of "less is more" developed. All these successive movements also influenced each other.

It can be said that the Bauhaus school forms the basis of today's furniture. In this period, for the first time, standardization for furniture production, ease of assembly and using new technologies started to produce higher quality furniture. It can be said that it includes similar approaches in terms of simplicity, linearity, logic of producing designs with low cost, and suitability for mass production.

Today, the use of wooden materials has become more widespread thanks to new technologies. In addition, plastic materials and industrial materials such as carbon fiber, fiberglass, polyurethane, polyethylene, and polypropylene are used. With geometric forms, designs in amorphous forms can also be produced. In today's furniture designs, as in Bauhaus designs, the simple design concept has been adopted, and the use of thinner steel profiles, which emphasize lightness, has been replaced by the use of thinner section steel profiles today.

Today, the concept of design has been adopted for everyone in the field of design and the designs have started to gain universal quality. Universal design, which emerged with the development of barrier-free and accessible concepts, was first mentioned in 1970. The aim is for the maximum number of users to benefit from designs, to be able to provide to the needs of each user. As an example of this design approach, today's furniture-related applications are as follows: Designing furniture to be used at different heights for children, elderly, disabled and all other users, removable shelves, an adjustable work surface for the desk at the desired height, allowing you to work standing and sitting, avoiding unnecessary complexity in furniture, giving priority to simple and comfortable use. Ensuring that it is easy to understand how to use it with the symbols placed on the moving furniture.

In the light of all these data, we see that the change in materials, design and usage areas by time by. Movements have a major role in the development of the material by enabling the use of them in different ways with the returns of the period they were adopted (Table 1).

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A MINI REVIEW OF THE STUDIES ON MASSIVE WOOD MATERIALS MACHINING AND SURFACE QUALITY

Sait Dundar Sofuoglu[1]

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Abstract

The purpose of this study was to analyse and evaluate the studies on massive wood materials machining and surface quality. It has been observed that these studies were performed in order to determine optimal wood machining parameters for obtaining the best surface quality on various wood species. A variety of visual techniques and surface roughness measurement methods are used and studied to be developed in order to determine surface quality. Determining the most optimal processing conditions for all wood species used in the wood machining industry will be useful in terms of productivity, quality, and cost and so on.

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Corresponding Author

Sait Dundar Sofuoglu
sdundar.sofuoglu@dpu.edu.tr

Phone: +90-274-4435050
Fax: +90-274-4430381

[1] Kutahya Dumlupinar University, Department of Woodworking Industrial Engineering, Kutahya, Turkey

A MINI REVIEW OF THE STUDIES ON MASSIVE WOOD MATERIALS MACHINING AND SURFACE QUALITY

Sait Dundar Sofuoglu
sdundar.sofuoglu@dpu.edu.tr
ORCID : 0000-0002-1847-6985

1. Introduction

It has become a necessity to more efficiently treat and to use longer wood materials, which have been an irreplaceable raw material in the life of man throughout history, because of the constantly decreasing forests. The quality can be increased via determining the surface quality of the piece in accordance with the smoothness of the surfaces to be created via the treatment of the wooden materials with tools and machinery and eliminating the negative factors in the treatment phases. When treatment properties are mentioned, it is usually meant the performers obtained as a result of the planning, sanding, boring, shaping, mortising and turning of the wooden material to obtain smooth surfaces. Surface characteristics of wooden materials play an imported role in their use for final product manufacture.

Also, it is required that the surface of the wooden material is smooth for good surface treatment (Aras et al., 2007). In recent years, the esthetical aspect of surface smoothness is considered rather than the functional aspect. Surface smoothness has been covered within the quality criteria of the customer for evaluating wooden materials (Aslandogan, 2005).

It is clearly observed that obtaining quality and smooth surfaces and knowing the treatment properties is extremely important, especially for massive wooden material. Therefore, in this study, studies made regarding the treatment and surface quality of wooden materials from the past to the present are investigated and assessed.

2. The studies performed on massive wood materials machining and surface quality

Various studies have been made regarding the treatment and surface quality of wooden materials from the past to the present with different points of view.

Davis et al. (1954) reported that; the effect of certain machining factors on the quality of wood finish and on power consumed in operating a molder in their study. The five principal hardwoods (yellow birch, red gum, hard maple, white oak, yellow poplar) and the three principal softwoods (Douglas-fir, ponderosa pine, southern yellow pine) were studied. These tests were performed two types of cutter materials (high-speed steel and carbide), five cutter head speeds (3600, 4800, 5400, 6000, 7200 revolutions per minute), two moisture contents (6% and 20%), five feed-speed combinations (60, 80, 90, 100, 120 feet per minute), and five cutting angles (0^o, 10^o, 20^o, 30^o, 40^o). That results obtained from the study as follows; if the quality of finish is poor at 8 or 10 knife cuts per inch, adjust the feed rate or cutterhead speed to get at least 16 knife cuts, When the knives are jointed in the head, keep a close watch on the lands, or jointed portion of the edges. The lands form part of the cutting circle and have no clearance. Finishing cut on the face of the work should be made as much as shallow. If the amount of chipped grain is excessive, the cutting angle of the knives reduces by 10^o at least. For minimum raised or fuzzy grain, drier lumber was used just as far as practicable.

In his work titled "Three "musts" for good machining", Davis (1959) stated that good machine work has three basic requirements: a machine in good mechanical condition with cutting tools reasonable sharp, a machine properly adjusted and operated, wood properly seasoned and selected to meet the needs of the job. In this study are given detailed information about knife angles, depth of cut, moisture content, rate of growth and density.

In his study Davis (1960) made studies on the machining properties of ponderosa pine and Douglas fir and their density and growth rate. According to the results of the study, both the number of rings per inch and the specific gravity of a given sample of ponderosa pine or Douglas-fir affect its machining properties to the degree that is highly significant, at least for the more exacting uses. In ponderosa pine and Douglas-fir, the number of rings per inch has more effect on the machining properties than does specific gravity.

His study titled "Surface-texture measurements for quality and production control", Stumbo (1960) compared surface textures of sawn, planed, molded and sanded surfaces; presented surface-profile indices and suggested their use for quality control and waste prevention. According to the study, the surface texture must be determined and analysed to control the surface of a wood product.

Davis (1962) gave short information about fuzzy grain in planning operations. He classified the factors occurring fuzzy grain such as cutter sharpness, moisture content, cutting angles, grinding bevels, excessive heel build-up, tension wood, depth of cut, feed rate, peripheral speed.

Stumbo (1963) said that the stylus tracer technique is the most accurate method in measurement and analysis of surface texture of wood.

Cantin (1965) determined the machining properties of a number of sixteen Eastern Canadian Woods. The operations were as follows: turning, planning, boring, mortising and shaping. The ten hardwood species studied were: white ash, large-tooth aspen, trembling aspen, basswood, beech, white birch, yellow birch, hard maple, red maple and red oak. The six softwood species were: balsam fir, black spruce, white spruce, jack pine, red pine and white pine. In planning, seven cuts 1.6 mm deep, under different sets of conditions covering four cutting angles (15^o, 20^o, 25^o, 30^o) and four numbers of marks per inch (8,12,16,20) were performed. According to the study results, in turning, the best turnings were usually obtained, being those with relatively high density and many rings per inch.

Peters et al. (1966) made studies to determine some machining properties (planning, shaping, turning, boring, and mortising) of two wood species grown in Hawaii Molucca albizzia and Nepal alder. According to the result of the study, best results were obtained when the wood materials were planned with a 10-degree cutting angle. Both Molucca albizzia and Nepal alder should be suitable for core stock, provided sufficient straight-grained material is available. Nepal alder could probably be used for some medium-value furniture parts.

A great amount of effort has been devoted to measuring wood surfaces. With few exceptions, each investigator used a different measuring method. Three methods are predominant - visual, light sectioning, and stylus tracing – but no system has been completely satisfactory (Stumbo, 1963).

In his work titled "Cross - grain knife planning hard maple produces high-quality surfaces and flakes" Steward (1970) investigated the surface roughness of some Hard maple panels from tree materials machining in the planning machine. The panels were planed (cross and parallel to grain) at 36 prescribed machining combinations of four rake angles (10, 20, 30 and 45 degrees), three depths of cut (0,8 mm, 1,6 mm, 3,2 mm), and three feed rates (10, 20 and 30) knife marks per 2,54 cm. According to the study results, maximum surface roughness was less for planning cross grain than for planning parallel to the grain, but average surface roughness was about the same for both methods.

In their study titled "Measuring wood surface smoothness: A proposed method" Peters and Mergen (1971), developed a stylus tracking device for the measurement of a wood surface. As a result, a precise method for measuring wood smoothness would be useful in laboratory development and manufacturing quality control. Tests showed that it had sufficient range and sensitivity to show wood anatomy as well as 0,25 inch–deep roughness. The complete system, included a head assembly, balancing network, amplifier, calibrating networks, and recorder, detected many degrees of roughness in trails.

In their study titled "Air-flow method measures lumber surface roughness" Porter et al. (1971) described a simple inexpensive device. A practical, inexpensive device was designed and tested for the measurement of relative surface roughness of circular-sawn and band sawn lumber. The instrument measures the quantity of air required to maintain a constant pressure differential between an inner pocket reservoir placed over the wood surface and the atmosphere. The device should prove helpful to lumber producers interested in improving the surface of their sawn lumber.

In their study titled "Boring deep holes in Southern pine", Woodson et al. (1972) investigated the boring operation in massive wooden material. Southern pine specimens and two bit types (double-spur, double-twist machine bit; ship auger) were used. According to the results of the experiments, in boring along the grain, the ship auger made better holes than the machine bit when the wood was dry; in wet wood hole quality didn't differ between bit types. When boring across the grain, the machine bit made better holes in both wet and dry wood.

In his work titled "Machining properties of wood", Kurtoglu (1981) stated that when machining properties are mentioned, it is usually meant the performers obtained as a result of the planning, sanding, boring, shaping, mortising and turning of the wooden material in order to obtain smooth surfaces and gave brief explanations regarding these operations. He explained and classified the errors occurring in the machining of the wood as raised grain, fuzzy grain, chipped grain, chip marks. He itemized the conditions necessary for a good treatment, made an explanation regarding the force requirement in treatment activity, and stated that the force requirement depended on specific gravity, moisture content of the wood, cutting angle, feed speed, speed of the cutter head, and cutter types. At the end of the work, he explained the factors to be considered to avoid the errors occurring during the treatment of wood.

In his work titled "Characterizing the roughness of southern pine veneer surfaces", Faust et al. (1986) used Southern pine veneer samples. A stylus tracing technique was used to obtain surface profiles. Veneer samples were visually classified into three roughness classes (rough, intermediate, and smooth).

Five indexes were calculated after each of eight levels of roughness grade had been removed from the profiles. The five indexes were evaluated by an analysis of variance for their ability to distinguish the three roughness classes and tight and loose veneer sides.

Faust et al. (1986); made a study to determine the effect of veneer surface roughness on glue bond quality in Southern pine plywood. According to results of the study confirm the undesirable effects of veneer roughness on Southern pine plywood glue bond quality, especially; when measured by industry standards. In addition, when conditions for over penetration exists (short assembly time and low veneer temperature), rougher glue lines will further reduce glue bond quality in terms of wood failure. The image analysis technique appears to be adequate to measure veneer roughness at production speed (100 fpm) within some constraints (Faust, 1987).

In their study titled "Effect of tooth geometry on surface quality of sawn timber in band saws", Ors et al., (1991) investigate the effect of the tooth geometry of band-saws on the surface quality of timber. They established the most suitable tooth profile through sawing Scotch pine (*Pinus silvestris* L.) lumbers according to the tooth geometries prepared in 4 different groups for band-saws. According to the study results, the best surfaces quality is established on lumbers sawed with saws with PV tooth (skewed tooth) profile with all the teeth smashed and equalized. This was followed by lumbers obtained with saws with four PV teeth smashed and equalized and one tooth left smooth, with two PV teeth crossed, and one tooth left smooth, and four PV teeth crossed and one tooth left smooth. The worst surface has occurred in timbers produced with saws having NV (sharp tooth) crossed teeth due to the breaking of the teeth. or the sawing process carried out with saws with crossed teeth, it was stated that the surface quality gradually deteriorated as a function time. This was caused by the deterioration of the crosses depending on the increasing number of lumbers sawn the deviations in the tooth geometry.

In the master's thesis titled "The effect of feed speeds and planning machines to surfaces quality in wood industry", Gurtekin (1996) investigated the effect of the cutting and moving speed of the wood planning machines used in the woodworking industry on the smoothness of the planed wooden surface and on the quality. Woods of oriental beech and larch tree have been used as experiment samples. The investigation has been carried out based on defects such as surface smoothness, raggedness, blade mark, burn formation, etc., as quality factors. At the end of the study, it was concluded that increasing the number of plates and the cutting speed and decreasing the feeding speed improved the wooden surface quality.

In the study titled "Faults occurring in the machining of wooden material", Kurtoglu (1996) stated that defects such as raised grain, fuzzy grain, chipped grain, chip marks in the machining of massive wooden material. In the study, such defects occurring in the treatment of wooden material have been individually explained, and the reasons for occurrence, on which tree types they are more generally encountered, and the precautions to be taken against those are indicated.

In the master's thesis titled "The effects of circular saws on surface roughness at wooden materials", Demirci (1998) compared the surface roughness after the wooden materials have been sawn with circular saws. In his study, he determined the surface roughness value on samples prepared from oriental beech, Scotch pine, durmast oak and acacia based on the tree type, cutting direction, a number of teeth, and feeding speed. In the results of the study, Scotch pine wood gave the smoothest surface and oak wood the roughest surface under the same trial conditions. The smoothest surface was obtained with the circular saw with 24 teeth at a 5 m/min feeding speed at radial directions. Also, radial cross-sections, give smoother surfaces in comparison to tangential cross actions; surface roughness increases with the increasing feeding speed; the smoothest surface was obtained with a circular saw with 24 teeth at radial directions; the roughest surface was obtained with a circular saw with 40 teeth at the radial direction; and no significant difference was observed on the oak wood amongst saws with regards to surface roughness.

Gurleyen (1998) made studies to compare the surface smoothness of massive wooden materials after machining with cutters in his master's thesis titled "Comparison of surface smoothness in the materials of solid wood used in the furniture". Tree type of oriental beech, Scotch pine, oak and acacia were used in his experiments. According to the results of the experiments, the smoothest surface was obtained from Scotch pine wood and the most roughest surface from oak; with regards to interaction of tree types and blade numbers, the smoothest surface was obtained from acacia wood in 4-blade planning, and the roughest surface from oak wood with 2-blade cutter; smoother surfaces are obtained in tangential cross-sections compared to radial cross-sections and in 4-blade planning compared to 2-cutters planning; the direction and type of the cutters were found statistically insignificant.

In their study, Williams et al. (1998) determined machining and related mechanical properties of 15 British Columbia wood species. Within this scope, they carried out turning, planning, sanding, boring, mortising and shaping. The machining tests were conducted according to ASTM D 1666-87. The surface quality of each sample tested was examined both visually and by touch. The most common defects were raised grain, fuzzy grain, chip marks, crushed grain and rough end grain. The results of the six machining tests are summarized in a table.

Korkut (1999) intended to establish the parameters providing quality of the optimum surfaces through theoretical and applied studies to determine the factors affecting the lumber surface quality in his master's thesis titled "Studies on the improvement of surface quality in lumber production". In this study, Scotch pine logs were used; sawdust weight method was used to determine the surface roughness; and the effects of log humidity amount, usage time of saw plates, type of teeth, amount of crosses, and feed speed on lumber surface roughness were evaluated. According to the results of the study, it was established that lumber surface roughness increased with the increasing log humidity, that no significant increases occur during the use of stellite saw plate for 0 and 2.30 hours, that saw plates with PV tooth type give smoother lumber surfaces compared to saw plates with NV tooth type, that there is no significant difference between the surface smoothness values obtained from lumber manufacture with saws having one-sided cross amounts of 0,8 ± 0,05 mm and 0,6 ± 0,05 mm, and that the lumber surface smoothness increases with increasing feed speed.

Lihra et al. (1999) intended to determine the manufacturing properties of nine Eastern Canadian softwood species (jack pine, red pine, Eastern white pine, black spruce, white spruce, balsam fir, tamarack, Eastern white cedar, Eastern hemlock), five Eastern Canadian hardwood species (yellow birch, white birch, sugar maple, red maple, trembling aspen) and three European and Asian species (Scotch pine and Norway spruce from Europe and sugi from Asia). They carried out planning, sanding, boring, mortising, shaping, turning, screw withdrawal and nail withdrawal properties. According to the study; Red pine showed the best average performance of all tested species showing no major defects in any of the performed machining tests. Yellow birch and sugar maple were the best performing hardwoods. Trembling aspen reached a high average score but performed poorly in the sanding test due to fuzzy grain. Black spruce and Eastern white pine showed good and uniform machining qualities in all tests.

Malkocoglu et al., (1999) referred to the importance of surface roughness and made definitions regarding surface roughness and roughness in their collected work titled "Historical development of surface roughness studies". They stated that the surface roughness studies first started in the metal industry and explained their historical development starting from 1930. After mentioning the formation of surface roughness in wooden material, factors affecting the surface roughness, and the classes of surface roughness (texture), they gave information about the importance of surface roughness. They stated that surface roughness evaluations could be carried out qualitatively and quantitatively. Each of the method had advantages and disadvantages such, as measurement speed, sensitivity, and giving accurate results.

In their study titled "The effect of planning and sanding on surface roughness of massive wood", Ors et al., (1999) investigated the effects of wood type, cutting direction, number of cutters, grit sizes, and feeding speeds on surface roughness of planed and sanded massive wooden materials, using oriental beech and Scotch pine. In measuring the surfaces roughness, they used a stylus tracing technique. As a result, smoother surfaces were obtained in oriental beech compared to Scotch pine after planning and sanding processes; surface roughness values were found to be lower in both tree types in the direction tangential to the annual rings compared to the radial direction; with regards to interaction of tree type and number of plates in planning, the smoothest surface was obtained in oriental beach with 4-cutter heads planning and the roughest surface in Scotch pine with 2-cutter heads planning; with regards to interaction of tree types and grit sizes, the smoothest surfaces were obtained from oriental beech with 120 grit sandpaper; with regards to interactions of tree types and cutting direction, number of cutters (planning), and grit sizes (sanding), the average smallest surface roughness value was obtained in oriental beech in a direction tangential to annual rings with 4-cutter head planning and number 120 grit sandpaper; and the surface roughness values were found to be higher in the feeding speed of 9 m/min compared to 5 m/min for planning and 20 m/min compared to 5 m/min for sanding.

In their study titled "The investigation on the improvement of the surface quality in sawn timber production", Kantay et al. (1999) intended to determine some significant factors affecting surface roughness in lumber production and establish the most suitable values related to such factors for optimum surface quality. As a result, they determined that surface roughness does not change with increasing log moisture content over the fiber saturation point, that no significant increases occur during the use of stellite saw plate for 2.5 hours, that saw plates with PV tooth type (curved tooth) give smoother lumber surfaces compared to saw plates with NV tooth type (sharp tooth), that there is no significant difference between the surface smoothness values obtained from lumber manufacture with saws having one-sided cross amounts of 0,8 ± 0,05 mm and 0,6 ± 0,05 mm, and that the lumber surface smoothness increases with increasing feed speed.

The planning, shaping, boring, turning and mortising properties of white spruce wood from a provenance trial and a natural stand were evaluated by Hernandez et al. (2001). This research showed that wood of white spruce grown in plantations has a good performance for planning, shaping and boring processes and poor performance for turning and mortising processes. The best planning condition was obtained at a 15^o rake angle and 20 knife marks per inch of feed speed.

In their study titled "Investigation of surface roughness of sliced walnut and beech veneers produced in Turkey", Kantay et al. (2001) compared the surface roughness values of sliced veneer plates obtained from walnut and beech from Turkey with the surface roughness values of veneers produced in other countries. In measuring the surfaces roughness, they used a stylus tracing technique. The average roughness values of the veneer plates obtained from factories were found to be R_a= 8,95 μm for walnut tangential, R_a= 10,66 μm for walnut radial, R_a= 10,67 μm for beech radial, and R_a= 9.33 μm for beech tangential. The surface roughness values of tangential sliced veneers were found to be lower than the values of radial veneers. Also, differences were found in the surface roughness values of watered walnut and beech radial and tangential sliced veneers. They concluded that this difference may result from the growing location, annual ring structures, vaporizing conditions (temperature, duration), angle and openings of the veneer cutting machine, sharpness of the veneer cutting blade, cutting speed, the temperature and moisture content of the lumber during cutting, and the conditions for veneer drying.

In their study titled "Investigation of surface roughness of oak and beech wood parquets produced in Turkey", Unsal et al. (2002) intended to gain knowledge on surface roughness values of massive parquets produced from oak and beech in Turkey and to compare these with the surface roughness values of parquets produced in other countries. In measuring the surfaces roughness, they used a stylus tracing technique. The factory average was found to be R_a= 5,18 μm for oak tangential parquets and R_a= 5,07 μm for oak radial parquets, R_a= 4,73 μm for beech tangential parquets and R_a= 5,19 μm for beech radial parquets. The roughness values of beech parquets cut tangentially were found to be lower than the ones cut radially. While there is no significant difference between the two cutting directions for oak parquets, it was determined that the surface roughness of parquets cut tangentially was higher.

In their study, Ilter et al. (2002) intended to measure and evaluate the surface roughness of planed and sanded fir tree experiment samples after having been cut tangential and radially at humidity of the %12 and %30 in accordance with the feeding speeds applied in planning and sanding processes and to enhance the final use quality. The surface roughness was established via contacting a stylus tracing technique with regards to tree types, number of cutters, grit sizes, feeding speeds, and moisture content changes. They were treated in the planning machine with 2 cutters, 3 cutters and with feeding speeds of 5 m/min and 10 m/min. As a result, the smoothest surfaces were obtained on the planning machine at a moisture content of %12, with radial cut and 2 blades, and at a feeding speed of 5 m/min. It was concluded that smoother surfaces were obtained with the increasing grit sizes.

In their work, Goli et al (2003) made studies surface quality and surface formation mechanics some specimens of Douglas fir and oak have been routed at different grain angles with a 3-axis CNC machine, with up-and down-milling techniques.

Efe et al. (2003) used the tree types of acacia catechu and plain walnut in their studies and investigated the effects of cutting direction, number of cutters, and number of revolutions on the surface smoothness. The experiments were carried out at 4400, 6000, 7800, and 10,000 revolutions/min. With, 2 and 4 cutters in radial and tangential directions. At the end of the experiments, the best results were obtained for acacia in the tangential direction amongst the directions, at 10.000 revolutions/min amongst the number of revolutions and with four cutters amongst the cutters. The roughest surface was obtained for acacia and walnut woods at the radial direction with 2 cutters at 4400 revolutions/minute.

In their study titled "Studies on surface roughness of Scots pine and Chestnut timbers", Kilic et al. (2003) investigated the tree types, number of saw teeth, and feeding speeds on the surface roughness of cut massive wooden materials. According to the experiment results, the smoothest surface was obtained for Scotch pine wood with a 40-teeth saw the roughest surface for chestnut wood with 24-teeth saw. As a result, they stated that the Scotch pine and chestnut woods used commonly in furniture and woodworking industries might be cut with a 40-teeth saw at a feeding speed of 5 m/min to increase the surface quality.

In their study, Ors et al. (2003) investigated the effects of cutting direction and sanding on the surface smoothness for acacia and oak woods. According to the results of the study, smoother surfaces were obtained with acacia wood compared to oak, with wooden materials sanded tangentially compared to the radial direction, and with regards to number 80 sandpaper compared to number 60 and 40 sandpapers and the interactions of tree type-cutting direction, tree type-sandpaper type, and cutting direction-sandpaper type were found insignificant. The smoothest surface was obtained for the tangential cross-section of Acacia wood with 80 grit sandpaper.

In his study titled "Research on determination of surface roughness of Crimean pine wood", Aslandogan (2005) intended to determine the surface smoothness values of samples from the larch tree grown artificially after the planning and sanding processes. According to the results obtained from the study, the tangential cross-section of the larch tree grown artificially gave smoother surfaces compared to the radial cross-section, number 80 sandpaper compared to 60 grit sandpaper, and 3 cutters compared to 1 cutter. The wood from the larch tree gave average surface roughness values in the tangential cross-section compared to the radial cross-section. In the study, it was seen that the smoothest surfaces on larch tree samples were obtained in the 3-cutters planning carried out in the tangential direction.

A new type of sensor for three–dimensional evaluation of surface geometrical properties is presented by Sandak et al. (2005). The shadow scanner method was evaluated for rapid and accurate scanning of surfaces of various porous materials, particularly wood and wood based materials in both laboratory and industrial applications. It is suitable for industrial application. Surfaces were scanned without contact; thus, surface damage during measurement was avoided.

In his study titled "Surface roughness studies", Korkut (2005) gave short information regarding surface roughness and listed some researches carried out in Turkey and other countries on surface roughness to give some concise information.

In his study, Sogutlu (2005) investigated the effects of the cutting direction and sandpaper type on the surface roughness of wooden materials. He conducted his studies on woods of tree types such as acacia, pear, chestnut, durmast oak, and Taurus cedar. According to the results of his study, the highest surface roughness was obtained in oak, followed by chestnut, acacia, Taurus cedar, and pear. He stated that wooden materials with coarse textures gave rougher surfaces compared to the ones with fine textures.

In their study titled "The effect of planning on the surface roughness in wood material", Sonmez et al. (2005) investigated the surface roughness of some samples from tree materials treated in the planning machine. In this study, they used woods from acacia, pear, chestnut, durmast oak, and Taurus cedar. According to the results of the study, the highest surface roughness was obtained in oak and the lowest in pear; rougher surfaces were obtained in the radial direction compared to the tangential direction and in 2-cutters planning compared to the 4-cutters planning; the difference between in the tangential and radial directions for the Taurus cedar and the roughness values in the tangential direction was found to be less than in the radial direction, while oak displayed a different situation in that rougher surfaces were obtained in the radial direction. Also, they concluded that materials with coarse texture gave rougher surfaces than materials with fine texture, that roughness was more in the radial direction and was inversely proportional with the number of cutters used in planning, and that surface roughness decreased with the decreasing feeding speed.

In their study, Malkocoglu et al. (2006) determined the treatment properties of oriental beech, Anatolian chestnut, hairy alder, Scotch pine, and Oriental spruce woods grown in the Eastern Black Sea region. They carried out planning, milling, drilling, mortising, and sanding within this scope. In planning, the best surface quality was obtained at cutting angles of 15°-10° for hard trees and at cutting angles of 15°, 20°, and 25° for soft trees. Similarly, the best treatment performance was obtained for oriental beech at 25-20 knife marks on 25 mm and for other tree types at lower feeding speeds, that is at higher number of knife marks (20 knife marks). In this research, oriental beech amongst the hard trees displayed the best performance in all the treatment characteristics. When assessed in general, hard the types give higher quality treatment characteristics compared to soft tree types. Scotch pine amongst the soft tree types displayed a high-quality treatment characteristic despite its knotted structure. When the planning characteristics of wooden materials are observed, the best machining properties were obtained at low cutting angles (15°–20°). The woods from the soft tree types were not affected from wide cutting angles as much as the hard tree types were. The surface quality in the machining of the wooden materials increased with decreasing feeding speed or increasing the number of knife marks.

In their study titled "The effect of wood turning techniques on surface roughness of wood material", Aras et al (2007) carried out lathing via cutting and scraping technique on walnut, Oriental beech, linden, and poplar woods used commonly in lathing processes. They used empirical assessment criteria for surface assessment. They obtained the smoothest surface for lathed walnut via the cutting method and the roughest surface for lathed poplar via the scraping method. There were no significant changes in the surface smoothness values of poplar and linden. They suggested adopting the cutting method and walnut as the preferred material to obtain a smooth surface in lathing.

In his study, Malkocoglu (2007) made studies on the planning properties and surface roughness of woods from oriental beech, Anatolian chestnut, plain alder, Scotch pine, and Oriental spruce. In this study, he investigated the effect of cutting angle and feeding speed on the treatment quality. The lowest treatment characteristic was displayed by Oriental spruce. When the planning characteristics are considered, it was determined that oriental beech and Scotch pine displayed high values, Anatolian chestnut and alder medium values, and Oriental spruce low values. Especially, the treatment characteristics of wood displayed an increase with the decreasing cutting angle. According to the study, when the surface roughness at different cutting angles was analyzed, Oriental spruce and scotch pine displayed the best results with low roughness values. However, lower surface roughness values were observed for all the wood samples for the latewood than the earlywood. The surface roughness values were slightly higher for low cutting angles (15°) than wide cutting angles (20° and 30°). Increasing the feeding speed reduced the surface quality in planning and decreasing the feed speed improved the surface quality. All the wood samples except for the Anatolian chestnut displayed lower roughness values.

In their study, Ratnasingam et al. (2007) determined planning properties of rubberwood grown in Southeast Asian region. This study shows that for machine planning of rubberwood, the recommended cutter marks pitch length of 1.2 mm, achieved with a knife rake angle of 20°, will ensure the highest resultant surface quality and processing yield.

In his study titled "Effects of wood machining properties of some native wood species on surface quality" Sofuoglu (2008) determined machining properties of European black pine, Cedar of Lebanon Sessile Oak and Black poplar widespread used and grown in Turkey. Perfect surface quality was obtained for hardwoods Black poplar and Sessile Oak at 25° cutting angle of planning and for softwoods European black pine and Cedar of Lebanon at 15° cutting angle of planning. Average surface roughness (Ra) values were obtained as 6,780 μm, 6,338 μm, 4,836 μm, 4,740 μm, in Sessile Oak, Black poplar, Cedar of Lebanon, European black pine, respectively.

In their study, Bustos et al. (2008) determined hardness, planning and moulding properties of tamarack wood from natural forests were evaluated on kiln-dried specimens following three types of drying schedules namely, high-temperature, elevated-temperature, and conventional drying. According to the results of the study, machining and hardness properties appeared not to be differently affected by the drying process. The best planning condition was obtained at 10° rake angle and twenty knife marks per 25.4 mm cutting length. This research showed that tamarack wood grown in natural forests has a good performance for planning and moulding processes. The best planning condition was obtained at 10° rake angle and 20 knife marks per 25.4 mm of feed speed.

Skaljic et al. (2009) determined surface roughness values of planed beech, oak and fir specimens.

Farrokhpayam (2010) studied the characterization of surface defects in dark red meranti, melunak, and rubber wood in the planning process.

In their review study, Naylor and Hackney (2013); wood machining research is evaluated to determine the general cutting mechanics.

In his study, Owusu et al. (2015) determined planning and sanding properties of Volumes of timber logs (dead trees) in the Volta Lake in Ghana. Surface quality performance increased with decreasing rake angle and feed speed. The magnitude of the chipped/torn grain defects decreased with decreasing rake angle and feed speed.

In his study titled "Some machining properties of 4 wood species grown in Turkey", Sofuoglu (2014) determined machining properties of European black pine and Cedar of Lebanon as two softwood species and Sessile Oak, Black poplar. Generally, machining properties are the performance of the wood material versus of such as planning, shaping, turning, mortising, boring and sanding operations. Perfect surface quality was obtained for hardwoods Black poplar and Sessile Oak at 25° cutting angle of planning and for softwoods European black pine and Cedar of Lebanon at 15° cutting angle of planning.

An artificial neural network (ANN) approach was employed to predict and control surface roughness in a computer numerical control (CNC) machine. Five machining parameters (cutter type, tool clearance strategy, spindle speed, feed rate, and depth of cut) were used. The present research results can be applied in the wood machining industry to reduce energy, time, and cost (Sofuoglu, 2015a).

In this paper, CNC machining parameters were optimised using the Taguchi design method on the surface quality of massive wooden edge-glued panels made of European larch. Three machining parameters (tool clearance strategy, spindle speed, and feed rate) and their effects on surface roughness were evaluated. The surface roughness, both, increased with increasing feed rate. Optimal cutting performance was obtained for a tool clearance strategy of an offset 16000 rpm spindle speed and 1000 mm/min feed rate cutting settings (Sofuoglu, 2015b).

In their study, Belleville et al. (2016) determined machining properties of Australian plantation-grown eucalypts. Within this scope, they carried out turning, planning, sanding, boring, mortising and shaping. This research confirmed that high-density plantation-grown Australian hardwoods can perform well during moulding, drilling, sanding, and routing processes. However, turning trials showed to be difficult for *Eucalyptus cladocalyx*, *Eucalyptus camaldulensis* and *Corymbia maculata* from one location.

In this paper, the optimization of CNC machining parameters was conducted using the Taguchi design method on the surface quality of massive wooden edge-glued panels made of Scots pine. Five machining parameters (cutters type, tool clearance strategy, spindle speed, feed rate and depth of cut) and their effects on surface roughness were evaluated. Optimal cutting performance for Ra and Rz was obtained for Cutter 1, at a tool clearance strategy of a raster 16,000 rpm spindle speed, 1000 mm/min feed rate and 4 mm depth (Sofuoglu, 2017).

In their study titled "Planning and Turning Characteristics of *Gmelina arborea* Grown in Two Ecological Zones in Ghana", Mitchual et al. (2018) determined machining properties of *Gmelina arborea*. Ghana where *Gmelina arborea* is cultivated, a feed speed of 6 m/min at a 30° cutting angle produces the best planning performance.

This paper determines the machining properties and possible utilization of punak, meranti bunga, mempisang, suntai and pasak lingo originated from Riau Province. Research revealed that planning, shaping, boring, turning and sanding properties. Punak and pasak linggo had good and very good machining properties (Supriadi and Abdurracan, 2018).

The objective of this review paper is to review how it is affected by different machining factors. The current challenges associated with various machining factors, process monitoring, and sensor selection were identified and explained (Nasir and Cool, 2020).

The study aims to obtain optimum machining conditions by investigating the effect of machining parameters of bamboo material on surface quality. The evaluation was performed for four- machining parameters (cutters type, spindle speed, feed rate and depth of cut) and their effects on surface roughness. Roughness values increased with increasing machining depth and cutter feed speed. Roughness value decreased by increasing the number of blades in the cutter (Aykac and Sofuoglu 2021).

The effects of different machining parameters (cutting direction, end mill type, spindle speed, feed rate, cutting depth, tool diameter) on surface roughness values of thermally Scotch pine, eastern beech and linden cut in a CNC router machine were examined. Roughness generally decreased in the thermally treated wood materials. Spindle speed increased, the roughness values of all wood specimens decreased. The feed rate increased, the roughness values increased. The end mill type, feed rate, and spindle speed were the most influential parameters on the surface roughness (Budakci et al., 2021).

3. Conclusion

The following results are obtained when the studies are assessed in general.

For a good treatment in all the processes related to the treatment of the wooden materials, the cutters have to be sharpened, the machines have to be maintained and stable.

Placing blades at a large number to the blade head, it should be provided that all the cutters contributed to the cutting process within the same cutting circle.

Cuts that are not deep should be applied. The cuts should be superficial, and sometimes it is useful to make the first rough cuts, then the superficial last cut.

Surface quality is improved with the increasing number of cutter marks per unit distance. The number of blade marks per unit distance should be kept high. To increase the number of blade marks per unit distance, either the cutting speed should be increased or the feeding speed should be decreased.

The most appropriate feeding speed and the combination of blade numbers, which may differ for each tree type, should be provided.

Generally, treatment defects are observed in the parts without smooth fibres in the treatment of wooden material. The materials to be used should be with smooth fibres and be cleared from knot formations that might cause fibre deflection. It shall be appropriate not to use massive wooden materials with knots on areas on which a good surface quality is required during production.

Examining the studies, the most suitable cutters should be chosen for each wood type and they should be sharpened.

The most suitable treatment condition for each wood type used in the industry should be made into tables.

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