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RADIAL STICK SAWING OPTIMIZATION

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Abstract

Stability in wood is related to moisture content and annual ring direction. Many manufacturers choose radial material for less shrinkage and swelling ratios and uniform shape change avoiding deformations especially for layered and joined materials. Sawmill operators usually prefer quarter sawing diagram to obtain radial boards from logs for this purpose. However, quarter and another diagrams give solutions for only boards that have larger dimensions than sticks, which are commonly used layered materials.

In this study, radial stick sawing optimization from logs was aimed. For this purpose, commercially preferred logs with 200mm, 300mm, 400mm and 500mm diameter, and cylindrical shape, were drawn in CAD program. Commonly used sawing diagrams (live, quarter, around) were tried empirically basing on cross sections. However, studies showed that when tangential boards were sawn to obtain radial sticks, all sticks could not be radial due to annual ring direction, especially at the end of boards. Therefore, some diagrams were modified to obtain maximum radial stick yield.

Results showed that the radial stick yield can reach 57,8% and the yield increment reached max. 28,9% (12,97% in average) when the all diagrams for all logs were considered. Especially around sawing method gave maximum radial stick yield. It is originated from the diagram, which normally gives radial sticks from tangential boards. Furthermore, modified sawing diagrams gave better yields from commercially preferred diagrams. However, sawing process is becoming extended and complicated with them.

Otherwise, it is suggested that log sawing optimization programs should calculate lower dimensions than boards with considering secondary sawing process and annual rings can be drawn in program or scanned for evaluating board is radial or tangential.

Keywords: Log Sawing, Sawing Optimization, Around Sawing, Radial Stick

1. Introduction

Solid wood material changes dimensions according to moisture exchange with atmospheric environment within certain limits. Dimensional changes and shape deformation are serious problem especially in laminated and bonded wood products. They may not be considered in structural wood products e.g. Glulam. Otherwise they are more considered at multi-layered parquets, wooden door and window laminated profiles which are more sensitive changes at millimetric level. For example, stability of sticks is important at multi-layered parquets due to cupped sticks generates ondulation problem on finished flooring (Fig. 1). Ondulation isn't defined as a deformation in standards (TS 5204 EN 13756 (2004), TS EN 13647 (2015), TS EN 14342 (2008), TS EN 13489 (2017) etc.). Especially, convex and concave cup deformations are defined, however they were evaluated for all parquet width or length. Although it isn't considered in standards, end-users don't want to see it due to aesthetic problems.

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Figure 1: Above: Ondulation at finished multi-layered (laminated) parquet surfaces
Below: Tangential stick array in parquet

Dimensional change ratio is mainly related to wood specie, anatomic characteristics, defects and annual ring angle. For example, many angles at cross-section preserve cross section shape after drying. However cupping can occur at tangential lumbers having less annual ring angle than 45^{o}, while diamonding can occur at square lumbers having annual ring angle is 45^{o}. Most of factors affecting dimensional stability can be eliminated while choosing right raw material (log or lumber) or choosing right production process.

Optimization studies for log sawing are focused primarily quantity yield or quality yield with evaluating defects as fissure, knots. However, quarter sawing and around sawing were developed with evaluating sawing methods due to annual ring angle and solid wood material anisotropy. Then radial or tangential lumber began to take part in quality yield. On the other hand, in conventional log sawing methods, operators aim manufacturing lumbers with larger dimensions (e.g. 25mm x 50mm). However, many factories which are integrated with value-added wood products having narrower cross-section sizes as sticks. Because the aim change can production process. For example, it is known that narrowing cross-sectional dimensions decreases quantity yield (Kantay, 2005).

In this study, radial stick sawing optimization from logs was aimed. Otherwise quantity and quality (tangential or radial) yield change were evaluated with different sawing pattern.

2. Materials and Methods

Commercially preferred Fir logs with 200mm, 300mm, 400mm and 500mm diameter were drawn in drawing software (AutoCAD). Only cross sections of logs and sticks were considered determining effect of pattern while sawing sticks. Conventional live and around sawing diagrams were used. These diagrams normally give best solutions for produce boards, which have larger dimensions than sticks. In addition to all these, radial sawn were modified to determine alternative tangential lumber sawing method at the 400mm diameter log drawings (Fig. 2).

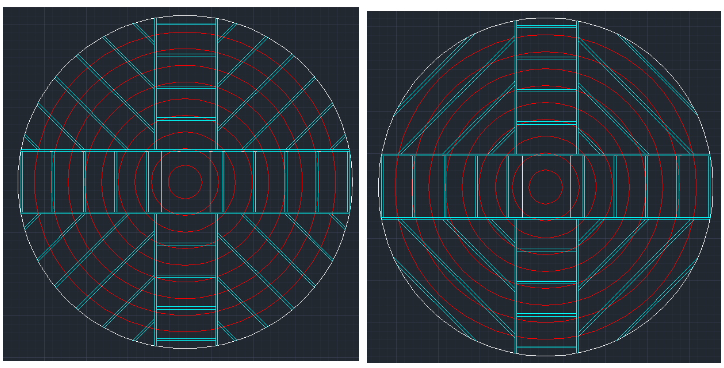

Figure 2: Left: Standard Radial Sawing Diagram, Right: Modified Diagram
(Red: Annual Rings, Blue: Saw kerf line)

The diagrams were determined empirically with aiming maximum stick number. 2,5mm saw kerf for board sawing and 3,15mm saw kerf dimensions for stick sawing were considered. Centre board with 77,5mm x 90mm dimensions was excluded to avoid stability and strength problems due to annual ring shapes and pith for each log. Sticks having dimensions with 35mm x 9mm and without wane were aimed.

Surface exit angles (α) of annual rings (20 mm width for each log) were considered to determine sticks were radial (α>45°) or tangential (α <45°). The angles were measured with drawing temporary lines in software as shown in Fig. 3.

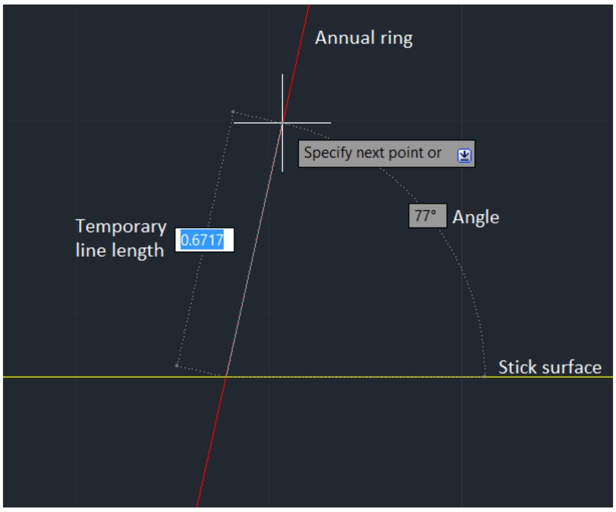

Figure 3: Surface exit angle measurement

Total sticks area was divided to log cross-section area for quantity yield, while total radial stick area was divided log cross-section area for quality yield (as shown in Eqs.1, Eqs.2, Eqs.3, Eqs.4 and Eqs.5).

$$\text{Total Stick Area (mm}^2\text{)} = \text{Number of sticks x Stick cross section area} \quad (1)$$

$$\text{Radial Stick Area (mm}^2\text{)} = \text{Number of radial sticks x Stick cross section area} \quad (2)$$

$$\text{Cross Section Area (mm}^2\text{)} = \pi \text{ x [Log radius]}^2 \quad (3)$$

$$\text{Quantity Yield (\%)} = \text{[(Total stick area / Cross section area of log)] x 100} \quad (4)$$

$$\text{Quality Yield (\%)} = \text{[(Radial stick area / Cross section area of log)] x 100} \quad (5)$$

Furthermore, radial sticks ratio in all sticks was determined (Eqs.6) due to laminated parquet companies reported that tangential sticks can't be utilized except burning to heat drying kilns.

$$\text{Radial Stick Ratio (\%)} = \text{[(Radial stick area / Total stick area)] x 100} \quad (6)$$

Moreover, economic gain was calculated with yield to compare sawing diagrams. For this, 2nd grade Fir log price (561 TL at 25th November 2017) was considered (Web-1) and sawmill capacity was based on 1250m^3/month log sawing capacity.

3. Results

The drawing tests were performed for each diameter of logs and they were shown at Fig. 4, Fig. 5, Fig. 6, and Fig. 7. After the figures, all results were shown in Table 1.

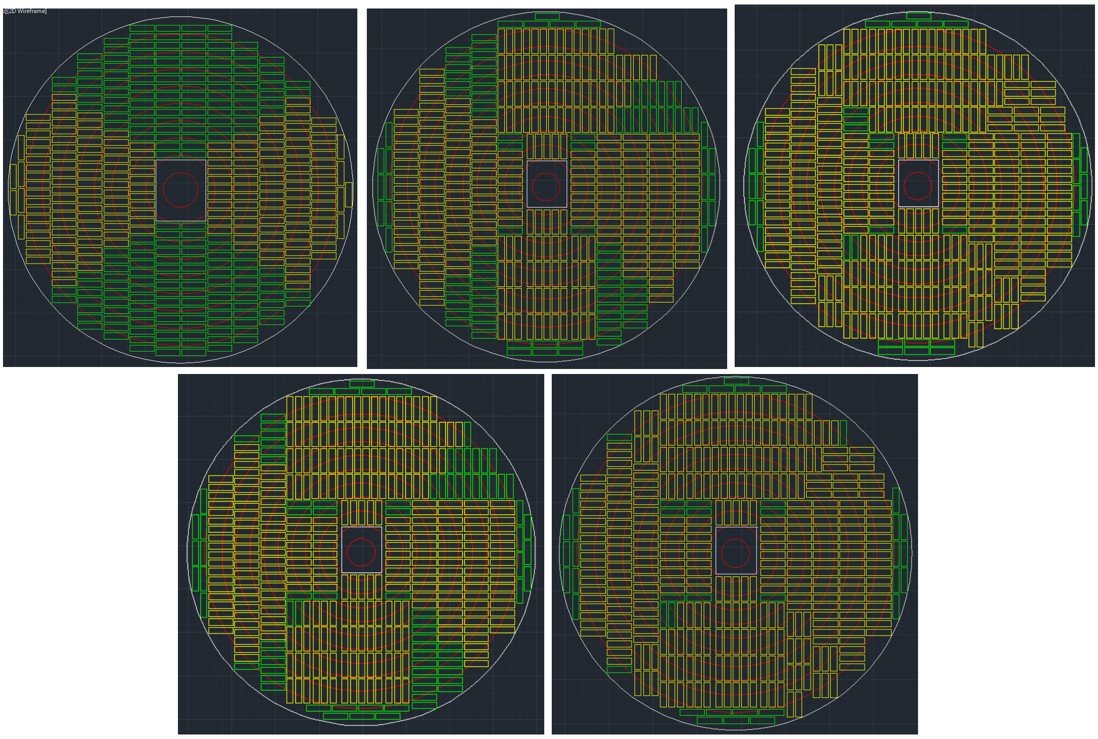

Figure 4: Sawing Diagram Possibilities for 500mm Diameter Log
(Live, Tangential-1, and Modified tangential-1, Tangential-2, and Modified tangential-2 sawing methods, respectively.)

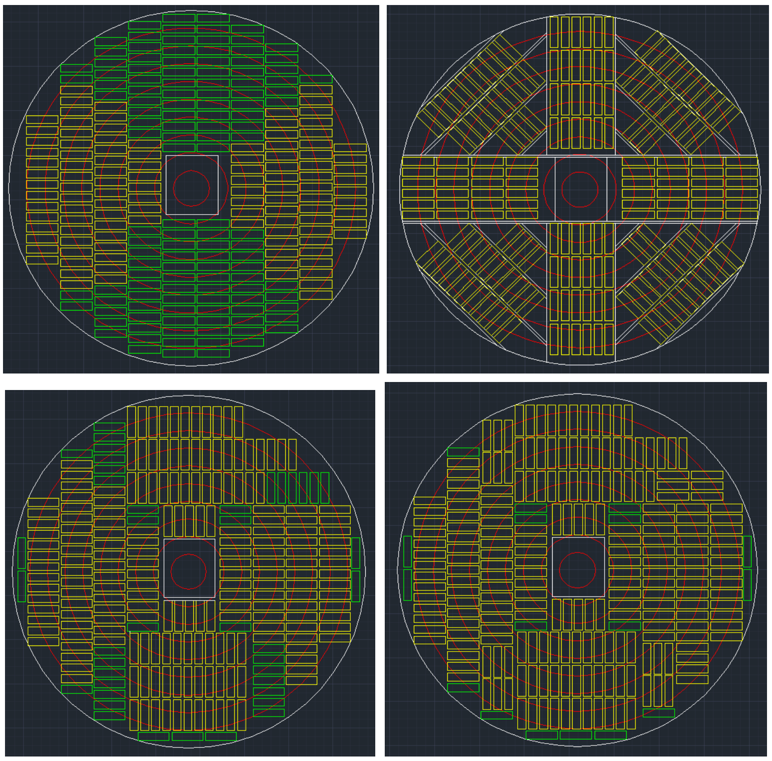

Figure 5: Sawing Diagram Possibilities for 400mm Diameter Log
(Live, Modified radial, Tangential and Modified tangential sawing methods, respectively.)

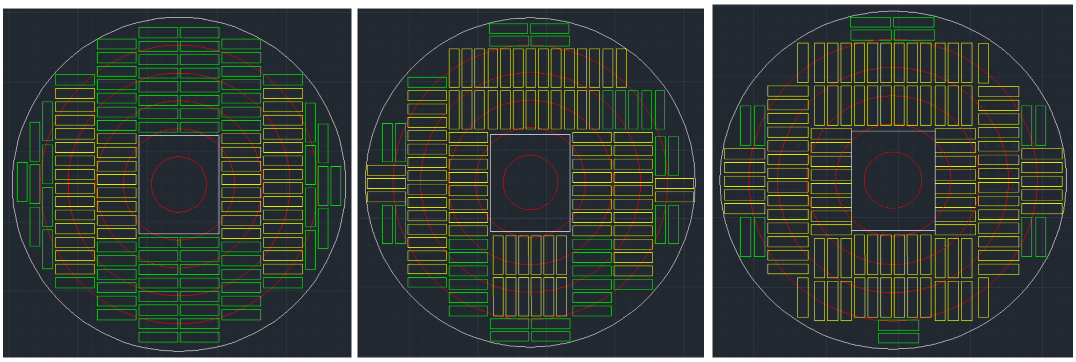

Figure 6: Sawing Diagram Possibilities for 300mm Diameter Log
(Live, Around sawing, Modified around sawing methods, respectively)

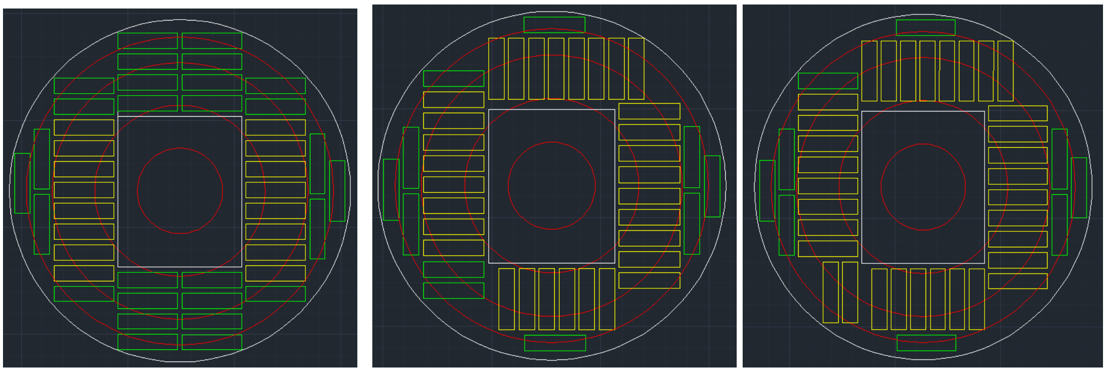

Figure 7: Sawing Diagram Possibilities for 200mm Diameter Log
(Live, Around, Modified around sawing methods, respectively)

Table 1: All results for each log diameter and each diagram

Log Diameter	Sawing Diagram	Total Radial Stick	Total Tangential Stick	Total Stick	Radial Stick Ratio (%)	Quantity Yield (%)	Quantity (Radial Stick) Yield (%)
500 mm	Live	180	200	380	47,4	61,0	28,9
	Around 1-1	283	101	384	73,7	61,6	45,4
	Around 1-2	344	37	381	90,3*	61,2	55,2
	Around 2-1	328	87	415**	79,0	66,6**	52,7
	Around 2-2	360**	53	413	87,2	66,3	57,8**
400 mm	Live	116	128**	244*	47,5	61,2*	29,1
	Modified Quarter	196	0	196	100**	49,2	49,2
	Around 1	194	41	235	82,6	58,9	48,7
	Around 2	218*	17	235	92,8	58,9	54,7*
300 mm	Live	44	80*	124*	35,5	55,3*	19,6
	Modified Live	106*	14	120	88,3*	53,5	47,3*
	Around	84	36	120	70,0	53,5	37,5
200 mm	Live	18	26*	44*	40,9	44,1*	18,1
	Around	31	11	42	73,8	42,1	31,1
	Modified Around	33*	9	42	78,6*	42,1	33,1*

Starred (*) values are the highest value of each diameter. Double starred (**) values are the highest value of each column for all diameters.

According to results, profit per month of sawmill with between choosing the best sawing pattern instead of the worst sawing pattern for radial stick production were calculated (Table 2).

Table 2: Radial stick yields and change with different sawing pattern for each log diameter

Log Diamaeter	Min. Radial Stick Yield (%)	Max. Radial Stick Yield (%)	Difference (%)	Profit* (TL)
500 mm	28,90	57,80	28,90	202661
400 mm	29,10	54,70	25,60	179520
300 mm	19,60	47,30	27,70	194246
200 mm	18,10	33,10	15,00	105188

*The profit was calculated with using monthly production values

4. Conclusion

Wood is an engineering material. Anisotropy, dimensional change, variety of tree species or wooden product etc. affecting factors should be considered and each production process of wood should be considered with detail. As seen in this study, changing sawing pattern with changing quality understanding can cause yield increase up to 28,9% with up to 202661 TL profit per month. When the ecological factors come into the forefront, the production can be performed with less log usage. In terms of economy, laminated parquet industry has many companies and even if 1TL difference for end-product price is important for getting ahead of rivalry.

In this study, the radial stick yield and profit change were compared to min. radial stick yield that can be determined with live sawing. The change can decrease when compared another sawing methods. Moreover, the waste utilization of the sawmills weren't considered. Many sawmills can use wastes for heat source for drying kilns and waste usage is calculated for reducing the heat costs.

Otherwise the production process is getting complicated with increasing radial stick yield. Because log-turning time increases in sawing patterns having better yield. It causes more production time and it needs more operator attention.

Conventional sawing diagrams give solutions to produce boards which have larger dimensions than sticks. Because these diagrams generally were prepared for headrig in primary breakdown process. However, diagrams can include end-products as radial sticks which can be produced in secondary breakdown process. Otherwise, it can be thought that diagram gives max. tangential boards can be used, cause of radial sticks can be produced with sawing tangential boards. But, this study showed that all tangential boards can't be fully sawn radial sticks due to annual ring shape. Furthermore, it is found that when the log diameter increased, radial stick yield increased. Because annual ring angle changes is getting more at the centre area of logs having smaller diameter.

In addition, sawing optimization programs developed in recent years started to consider annual ring to determine radial – tangential lumber. Today, determining annual ring shape of each log is difficult and it is calculated empirically. However, developed non-destructive evaluating devices as computed tomography can help to transmit the information of each log to the programs and healthier results can be obtained.

5. Acknowledgments

This study was presented in ORENKO 2018 – International Forest Products Congress held by Karadeniz Technical University, Trabzon.

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SOME NATURAL AND EXOTIC PLANT TAXA, WHICH ARE USED NON-WOOD FOREST PRODUCTS IN PARKS OF TRABZON

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Abstract

Trabzon contains many exotic and natural plant taxa in its green nature. These plant taxa have been used in the parks and gardens in order to ensure for local people benefit from this green nature in daily life. In order to benefit non-wood forest products, priority natural species have been brought to these areas. And also, exotic plant taxa have been exploited for aiming direction. 100th Year Park, Trabzon Fatih Park, Trabzon Square Park, Atapark, Ekopark, Olympic Park, Zağnos Valley park were studied and determined the floristic situation of these areas. Generally in these areas have; *Aesculus hippocastanetum, Berberis thunbergii, Betula pendula, Citrus* sp*., Coryllus avellana, Cotoneaster salicifolius, Cotoneaster nummullaria, Crataegus spp., Erica arborea, Eriobotrya japonica, Eucalyptus camaldulensis, Eucalyptus globulus, Fraxinus excelsior, Junglas regia, Juniperus communis, Juniperus virginiana, Lauroceracus officinalis, Laurus nobilis, Liriodendron tulipifera, Magnolia grandiflora, Malus floribunda, Morus alba, Nerium oleander, Olea europea, Pinus pinea, Platanus orientalis, Populus tremula, Prunus avium, Prunus cerasifera* "Atropurpurea", *Prunus persica, Pyrus communis, Rosa* spp., *Rosmarinus officinalis, Rhododendron ponticum, Rhus coriaria, Robinia pseudoacacia, Salix babylonica, Taxus baccata, Tilia platyphyllos, Tilia tomentosa* taxa. As a result of the study, it has been recommended that some different naturel and egzotic plant taxa will be used in these park and gardens.

Keywords: Trabzon, Non-wood, Natural, Exotic, Park

1. Introduction

Parks are natural areas that are designed within the boundaries of the city. They are largely composed of soft surfaces such as soil, grass, bushes, trees and shrubs. The parks in the city are important not only for human health and quality but also life of urban ecology. The plants are the most important elements of these areas. The appearance of the plant material in the parks, such as measurements, forms, textures, colors, etc., are carried a value for people in the city (Tercan, 1994; Eren, 2012).

People have started to move away from nature in recent years and they have started to live in the artificial environment that they were created. And they began to protect nature because of their miss for nature. Environmental problems such as rapid urbanization, industrialization and population growth, have been led people to prefer places where they can be intertwined with nature. Urban green areas, which are contributed to the city's open green space system and allowed for recreational activities, are very important areas for the city (Konaklı and Önder, 2005).

One of the most important objects of landscape design is plant materials. In addition to the colour, shape, form, texture of the plant that will be used for planning and design, choosing the suitable plant for planning and design will be made thanks to the knowledge of the growing environment of the plant, besides of the color, shape, form and texture of the plant. In addition, the possibility of supplying the plant species to be used also needs to be demonstrated (Ertekin et.al., 2010).

When plant design is carried out, some issues have great importance such as, ecological characteristics of plants, their significance in terms of landscape, and the right choice of destination and purpose of use in landscaping (Altınçekiç and Kart, 2007). People can get rid of the pressure on daily life and meet nature thanks to the planting design (Karaşah and Var, 2012). In addition, the first objective of

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the planting design is to contribute functionally to the park site and thus respond to the requests of the users in these areas (Robinson, 1992).

Plants, which are used in parks, should be evaluated in ethnobotany terms. Therefore, the concept of ethnobotanic has been researched and described by many people. The ethnobotanic term was described by John W. Harshberger, who is a biology professor, as "the use of plants by the local people" (Heinrich, 2004). Yıldırımlı (2004) is defined the ethnobotanic term in shortly as "the use of plants to meet the various needs of people".

Laurocerasus officinalis Roem, Rosa canina L., Sorbus torminalis L. Crantz, Sorbus aucuparia L., Crateagus monogyna Roem., Arbutus unedo L., Vaccinium arcthostophyllos L., Corylus avellana L., Pyrus communis L., which are grown naturally in Trabzon and its region, are preferred because of their features such as flower beauty, fruit beauty and autumn coloring rather than wood value in landscape architecture. These plants are widely preferred in landscapes of Europe and America, with their advantages such as general form features, medicinal fruity, ability to grow in different altitude steps (Atay, 1987; Kayacık, 1982).

In this research, the parks in the city center were considered as the study area. During the first step of the study, plant species in the study areas were identified. In the next step, the importance of the species in terms of non-wood products in parks and gardens was researched.

2. Materials and Methods

The floristic structure of the parks and gardens in Trabzon was investigated in the year of 2018. Within the scope of the study, plants from the study area were collected and identified. The plant taxa which particularly have non-wood significance were determined. It has also been investigated that for which purposes these plant taxa are used. As a result of detailed literature study (Güner et al., 2000; Bonnier, 1912-34; Lanzara and Pizzetti, 1997; Kreutz, 2009; Simpson, 2012; Yaltırık and Efe, 1996; Baytop, 1998; Mamıkoğlu, 2007), the listed taxa and some properties of these plant taxa were found out. In addition, these properties particularly have been determined from the "Flora of Turkey" (Davis, 1965-1985; 1988) and " Türkiye Bitkileri Listesi (Damarlı Bitkiler) (Güner et. al., 2012)".

3. Results and Discussion

As a result of the study, plant species which are used the parks and the gardens in Trabzon, were determined. Among these species, the species with non-wood importance have been determined by literature research. Conclusion of the study, some properties of plant species (type of plant, family, botanical name, common name, flowering season, flower colour etc.) were determined and showed in Table 1.

Table 1: Some characteristics of plant species, which were determined in the parks and the gardens in Trabzon, were demonstrated in the Table below.

Type of Plant	**Family**	**Botanical name**	**Common name**	**Flowering season**	**Flower colour**	**Deciduous state**	**Natural/ Exotic**
Climbing	Araliaceae	*Hedera helix*	Duvar sarmaşığı	August-September	Greenish	Evergreen	Natural
Shrub	Adoxaceae	*[1] Viburnum opulus*	Gilaburu	May-June	White	Deciduous	Natural
Shrub	Adoxaceae	*Viburnum tinus*	Filburnu	February-March-April-November-December	White	Evergreen	Natural
Shrub	Anacardiaceae	*Rhus coriaria*	Sumak	June- July	Greenish white	Deciduous	Natural
Shrub	Anacardiaceae	*Cotinus coggygria*	Boyacı sumağı	April-June	Whitish green	Deciduous	Natural
Shrub	Apocynaceae	*Nerium oleander*	Zakkum	April-September	Pink -Red	Evergreen	Natural
Shrub	Aristolochiaceae	*[2] Yucca* sp.	Avize ağacı	Spring and Summer start Summer mid end	Whitish yellow	Evergreen	Exotic

Continuation of Table 1

Shrub	Berberidaceae	*Berberis thunbergii*	Japon kadın tuzluğu	May	Yellow	Deciduous	Exotic
Shrub	Betulaceae	*Coryllus avellana*	Fındık	February-March	Red	Deciduous	Natural
Shrub	Cistaceae	*Cistus creticus*	Laden	May –June	Pink	Deciduous	Natural
Shrub	Ericaceae	*Vaccinium arcthostophyllos*	Likarpa	May - July	Whitish	Deciduous	Natural
Shrub	Ericaceae	*Rhododendron ponticum*	Kumar	March-May June-August	Purplish pink	Evergreen	Natural
Shrub	Ericaceae	*Erica arborea*	Funda	March-July	Pale pink-White	Evergreen	Natural
Shrub	Hydrangeaceae	*Hydrangea macrophylla*	Ortanca	Beginning of summer	White-blue-pink	Deciduous	Exotic
Shrub	Lamiaceae	*Rosmarinus officinalis*	Biberiye	February to May	Pale blue	Evergreen	Natural
Shrub	Malvaceae	*[3] Hibiscus syriacus*	[4] Kerkede	Winter beginning Summer Mid-summer End Autumn beginning Autumn middle Autumn end	Beyaz Eflatun Menekşe Mor Pembe	Deciduous	Exotic
Shrub	Oleaceae	*[5] Jasminum fruticans*	Boruk	May	Yellow	Evergreen or semi-deciduous	Natural
Shrub	Poaceae	*Phyllostachys bambusoides*	Gölge bambusu			Evergreen	Exotic
Shrub	Rosaceae	*Cotoneaster nummularia*	Dağ muşmulası	April- June	White	Deciduous	Natural
Shrub	Rosaceae	*Rosa canina*	Kuşburnu	April-September	White to pale pink - Rarely dark pink	Deciduous	Natural
Shrub	Rosaceae	*Cotoneaster salicifolius*	Söğüt yapraklı dağ muşmulası	June	White	Evergreen	Exotic
Shrub	Rosaceae	*Photinia x fraseri*	Alev çalısı	Beginning of spring-Mid-spring	Whitish	Evergreen	Exotic
Shrub	Rosaceae	*Pyracantha coccinea*	Ateşdikeni	April-June	Whitish	Evergreen	Natural
Shrub -Small tree	Buxaceae	*Buxus sempervirens*	Şimşir	April	Yellowish green-whitish	Evergreen	Natural
Shrub -Small tree	Ericaceae	*Arbutus unedo*	Kocayemiş	October-November	Greenish white	Evergreen	Natural
Shrub -Small tree	Oleaceae	*Ligustrum japonicum*	Lügüstrüm	Mid-summer End of summer Autumn beginning	White	Evergreen	Exotic
Shrub -Small tree	Rosaceae	*Crataegus spp.*	Alıç	April-May, June-July	White - Pink	Deciduous	Natural
Shrub -Small tree	Rosaceae	*Persica vulgaris*	Şeftali	March-April	Pink-red-- rarely white	Deciduous	Natural

Continuation of Table 1

Shrub -Small tree	Rosaceae	*Laurocerasus officinalis*	Karayemiş	April-June	White	Evergreen	Natural
Shrub-Tree	Cupressaceae	*Chamaecyparis lawsoniana*	Lawson Yalancı servisi	-	-	Evergreen	Exotic
Shrub-Tree	Cupressaceae	*Juniperus communis*	Ardıç	-	-	Evergreen	Natural
Shrub-Tree	Fabaceae	*[6] Acacia dealbata [7] [8]*	Gümüşi Akasya	Spring Mid Spring Summer Mid-Summer End Autumn Beginning	Yellow	Deciduous	Exotic
Shrub-Tree	Lauraceace	*Laurus nobilis*	Defne	March-May	Yellow	Evergreen	Natural
Shrub-Tree	Moraceae	*[9] Ficus carica*	İncir	March - April / May - June / August September	Whitish	Deciduous	Natural
Shrub-Tree	Oleaceae	*Olea europaea*	Zeytin	May	White	Evergreen	Natural
Shrub-Small tree	Rosaceae	*Eriobotrya japonica*	Yenidünya	April-May	White	Evergreen	Exotic
Small tree	Cupressaceae	*Juniperus virginiana*	Kurşun kalem ardıcı	-	-	Evergreen	Exotic
Small tree	Rosaceae	*Prunus cerasifera "Atropurpurea"*	Kırmızı yapraklı erik	April- May	Dark pink - white	Deciduous	Natural
Tree	Arecaceae	*Phoenix* spp.	Hurma	Mid-spring and end	Whitish	Evergreen	Exotic
Tree	Betulaceae	*Betula pendula*	Huş ağacı	April- May	Green	Deciduous	Natural
Tree	Betulaceae	*Alnus glutinosa*	Kızılağaç	April		Deciduous	Natural
Tree	Bignoniaceae	*[10] Catalpa bignonioides*	[11] Katalpa	Spring and Summer beginning Summer	Whitish	Deciduous	Exotic
Tree	Cupressaceae	*Biota orientalis*	Doğu Mazısı	-	-	Evergreen	Exotic
Tree	Fabaceae	*Robinia pseudoacacia*	Yalancı akasya	April-June	White - Yellow	Deciduous	Natural
Tree	Fabaceae	*Cercis siliquastrum*	Erguvan	April-May	Bright pinkish-purple	Deciduous	Natural
Tree	Fabaceae	*[12] Robinia pseudoacacia*	Yalancı akasya	April- May	Yellowish white	Deciduous	Natural
Tree	Fagaceae	*Fagus orientalis*	Kayın	May		Deciduous	Natural
Tree	Ginkgoaceae	*Ginkgo biloba*	Mabet ağacı	-	-	Deciduous	Exotic
Tree	Juglandaceae	*Juglans regia*	Ceviz	May	Green	Deciduous	Natural
Tree	Magnoliaceae	*Liriodendron tulipifera*	Lale ağacı	May-July	Yellow-Orange	Deciduous	Exotic
Tree	Magnoliaceae	*Magnolia grandiflora*	Manolya		White	Evergreen	Exotic
Tree	Malvaceae	*Tilia platyphyllos*	Yaz ıhlamuru	The beginning and the middle of summer	Yellowish white	Deciduous	Natural
Tree	Malvaceae	*Tilia tomentosa*	Gümüşi ıhlamur	The beginning summer	White	Deciduous	Natural
Tree	Moraceae	*Morus alba*	Akdut	May	Pale green	Deciduous	Exotic

Continuation of Table 1

Tree	Myrtaceae	*Eucalyptus camaldulensis*	Sıtma ağacı	November-May	White	Evergreen	Exotic
Tree	Myrtaceae	*Eucalyptus globulus*	Mavi ökaliptus		White-red	Evergreen	Exotic
Tree	Oleaceae	*Fraxinus excelsior*	Dişbudak	March- April	White	Deciduous	Natural
Tree	Pinaceae	*Pinus pinea*	Kızılçam	-	-	Evergreen	Natural
Tree	Pinaceae	*Cedrus spp.*	Sedir	-	-	Evergreen	Natural
Tree	Platanaceae	*[13] Platanus orientalis*	Çınar	March-May	Green	Deciduous	Natural
Tree	Plataneceae	*Platanus occidentalis*	Batı Çınarı	March -May	Brown-Green	Deciduous	Exotic
Tree	Rosaceae	*Malus floribunda*	Süs elması	April-May	White to pink	Deciduous	Exotic
Tree	Rosaceae	*Cerasus avium*	Kiraz	March -May	White	Deciduous	Natural
Tree	Rosaceae	*Pyrus communis*	Armut	April May	White	Deciduous	Natural
Tree	Rosaceae	*Sorbus aucuparia*	Kuş üvezi	May-June	White	Deciduous	Natural
Tree	Salicaceae	*Populus tremula*	Titrek kavak	March -May	White	Deciduous	Natural
Tree	Salicaceae	*Salix babylonica*	Salkım söğüt	April	White - Green	Deciduous	Natural
Tree	Salicaceae	*[14] Populus nigra*	Karakavak	March - April	Yellowish green-orange-pink	Deciduous	Natural
Tree	Sapindaceae	*Aesculus hippocastanetum*	Atkestanesi	May	White	Deciduous	Natural
Tree	Taxaceae	*Taxus baccata*	Porsuk	-	-	Evergreen	Natural

Our research was to aim the interactions between plants and human to live where parks and gardens are. In this present study, the plant species distribution and diversity pattern have been determined and their significance of parks potential characteristics were put forward. The whole plant materials are greatly important for parks and gardens in Trabzon. The distribution of ornamental plant species in parks are significantly related to rehabilitation purposes. Considering the determined plant taxa in parks and gardens, it was appeared that these species was to be much aimed to benefit as well as ornamental purposes. However, we need much scientific information and researching about knowing the socio-cultural effects on this distribution of plant species.

4. Conclusion

This study has been carried out within the city of Trabzon, in Black Sea Region of Turkey. A rapid urbanization as a consequence of a population increase of the city. Thus, numerous new parks were constructed in the city center. These areas are included mostly ornamental plant materials while the green areas of the city have been decreased at present.

As the result of the study, 70 plants taxa are used in ethnobotanical terms under 32 families were determined. The most common species are found from the families of Rosaceae (14) and Cupressaceae, Ericaceae, Fabaceae and Oleaceae (4). Most of these species (67,14%) are natural and (32,86%) exotic taxa. On the other hand, 40 (57,14%) taxa are deciduous and 30 (42,86%) taxa evergreen. In this study also, 1 climbing, 22 shrubs, 32 tree and 15 shrub-tree plant taxa were determined.

As a result, this study showed that these plant taxa were used especially for landscaping and rehabilitation purposes.

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FORMALDEHYDE EMISSIONS AND EFFECTS ON HEALTH DURING ARRIVAL OF FURNITURE TO ULTIMATE CONSUMER

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Abstract

People spend most of their time in closed areas such as home, office, school. For this reason, indoor environment pollution has great importance for human health. In this environment, the formaldehyde gas in the indoor furniture produced by the synthetic resin made from the panels is gradually released into the living spaces. The indoor concentration of formaldehyde gas in ppm is higher than the international standard, that is, the comfort limit value accepted by the western countries, which causes considerable damage to human health, especially to children.

In this study; formaldehyde emission values of five different companies' wood-based panel products determined by three different methods in Turkey and in 50 furniture manufacturing facilities, 50 furniture stores, 50 new apartments; formaldehyde gas analysis have been performed. As a result; on average, furniture manufacturing 0.45 ppm, in furniture store 0.37 ppm, in new apartments 0.11 ppm formaldehyde gas release has been measured.

Keywords: Formaldehyde, Furniture, Particleboard, MDF, Human health

1. Introduction

The simplest member of the aldehyde group, formaldehyde (H2C = O), is technically produced by the oxidation of methane and methanol. Formaldehyde can be generally described as a colorless, unscented substance. In forest products industry, urea is widely used as an adhesive in the production of wood-based composite materials such as chipboard, plywood and fiberboard by being condensed with melamine and phenol resins (Şahin, 2005).

Formaldehyde is classified by the International Agency for Research on Cancer as Group 2A as a carcinogenic substance (Soysal and Demiral , 2007). Studies have shown that formaldehyde contributes to the development of nasal and upper respiratory cancers and skin cancer (Muzi et al., 2004). The amount of formaldehyde in indoor environments is important because of the health effects and the common occurrence of indoor living areas as pollutants. Formaldehyde gas can enter the respiration of living things, the mouth and the skin through contact. In general, when the formaldehyde concentration exceeds a certain level and those suffering from formaldehyde may have complaints such as fatigue, headache (Emri et al., 2004).

Formaldehyde can be formic acid in the human body and is excreted in the urine. However, if formaldehyde is present in excess of a certain amount (> 1 ppm) in the human body, significant problems may occur in the central nervous system and respiratory tract (Emri et al., 2004).

Formaldehyde-based glues are preferred in the forest products industry due to their low price and ease of use. In the production of composite panel board (chipboard, fiberboard, plywood), it is used as cross-linking material. The high reactivity of formaldehyde allows it to pass easily to the atmosphere when it is in free state. Therefore, during the use of furniture and composite panel products manufactured using formaldehyde-based glue indoors, depending on atmospheric conditions, it may become formaldehyde emission in time (Şahin et al., 2011).

In a survey of urban and rural areas in Ankara, for the reason that formaldehyde levels in the living room and kitchen are higher than allowed and health problems such as eyebrows, runny nose, dry throat in home residents, formaldehyde level has been determined statistically significant high (Aksakal et al., 2005). The permissible exposure limit (PEL) for formaldehyde as determined by the OSHA (Agency for Safety and Health at Work) is 0.75 ppm for the 8 hours time average (TWA) (Vaizoğlu, 1998).

57 workers working in 100 furniture manufacturing factories in the Siteler Industrial Zone in Ankara stated that they were exposed to formaldehyde levels above 0.75 ppm and 1% of 229 workers were exposed to formaldehyde levels above 0.75 ppm for more than 8 hours (Evci et al. 2002).

A statistically significant relationship has been found between the levels of kitchen formaldehyde and the frequency of the occurrence of eyebrows, dry throat and runny nose in people living in these houses; complaints of eyebrows, dry throat and runny nose in households that kitchen formaldehyde level higher than 0.10 ppm is more frequent than those living in houses with lower formaldehyde levels than 0.10 ppm (Evci et al., 2002).

Formaldehyde has an unpleasant odor. Formaldehyde gas has an irritant effect on the skin, eyes and lungs. Some irritant effects can now occur even below 0.75 ppm PEL, which is reported by OSHA as the legal boundary (Rosenstock and Cullen, 2005). The formaldehyde level should normally be below 0.03 ppm in closed environments (CPSC, 1997).

Standard methods for the determination of formaldehyde emissions;

If the formaldehyde emission is expressed as the mixing of the wood-based material in contact with the air after the production process by dissolving the formaldehyde in the ambient relative humidity, it has been mentioned in the scientific publications as the important and remarkable chemical. Formaldehyde emission caused by especially wood-based materials is important due to environmental and health effects (Mentese, 2009).

According to formaldehyde emission rates in forest products industry the classification of the panel board products is shown in table 1.

Table 1: Formaldehyde emission limits of wood-based panels

Emission Class	Board Type	Formaldehyde Measurement Limit Values	Test Metod
E1	MDF, YL, OSB	≤0.124 mg/m^3 (0.09 ppm)	EN 717-1- Chamber Method
		≤8.0 mg/100g	EN 120 – Perforator Metod
		≤3.5 mg/m^2 h	EN 717-2- Gas Analysis Method
E2	MDF, YL, OSB	>0.124 mg/m^3 (0.09 ppm)	EN 717-1- Chamber Method
		>8.0 mg/100g ≤ 30 mg/100g	EN 120 – Perforator Metod
		>3.5 mg/m^{2}h ≤ 8 mg/m^{2}h	EN 717-2- Gas Analysis Method

Various standard methods are used for the determination of formaldehyde emissions. The relevant European Union, Japan and ISO standards are briefly summarized below (Salthammer and Mentese, 2008).

European Union Standards;

EN 717-1 (2004): Determination of release of formaldehyde from wood-based panels-Part 1: Emission of formaldehyde by Chamber method (Chamber method)

EN 717-2 (1994): Determination of formaldehyde release in wood-based panels-Part 2: Release of formaldehyde by gas analysis method (gas analysis method)

EN 717-1 (1996): Wood-based panels-Determination of formaldehyde release-Part 3: Formaldehyde release by bottle method (Bottle method)

EN 120 (1993): Wood-based panels-Determination of formaldehyde content- (Perforator method)

Japanese standards;

Japanese standard methods are very similar to the European Union standard methods, but there are some differences in the volume of the rooms used and the areas of the test materials.

JIS A 1460 (2001) and JAS MAFF 233 (2003): Building panels: Determination of formaldehyde emissions-desiccator method (Desiccator methods).

JIS A 1901 (2003): Determination of volatile organic compounds and aldehyde emissions from building materials-small chamber method (Small Chamber Method).

ISO standard;

ISO.7CD 12460 (2005): Chamber method

The purpose of this study is to convey the current effects of manufactured products on human health determining the formaldehyde emissions at each stage until the final consumption of the products produced using wood based plates and to remark and contribute for the preparation of legal regulations and limits on formaldehyde emissions for finished furniture in Turkey.

2. Materials and Methods

2.1. Material

Particleboards used for formaldehyde emission tests have been obtained from five different factories that makes production in Turkey. During sampling; 18 mm has been preferred which constitutes a significant part of the production of plants in Turkey. A plate with an average density of 620-650 kg/m3 in white color and a melamine coated upper and lower side has been used at an average of 2100 mm x 2800 mm from each factory and it is stated as A, B, C, D, E before giving company names.

2.2. Method

Kastamonu Entegre whose formaldehyde emission from particle boards is Türkak 's accredited. (TS EN 717-1 (chamber method), TS EN 717-2 (gas analysis method) and TS EN 120 (perforator method).

In Ankara and Bursa İnegol as the most common furniture production in Turkey as well as in Kastamonu Center selected as the pilot region, emission measurement points are determined. Totally, in 50 furniture manufacturing plants and 50 furniture stores measurements have been made. In Ankara,20 furniture manufacturing facilities, 20 furniture stores, 20 furniture manufacturing facilities, 20 furniture stores in Bursa İnegöl Region, 10 furniture manufacturing facilities and 10 furniture stores in the central region of Kastamonu.

In the center of Kastamonu, which was chosen as the pilot region and mostly provide furniture from Ankara Siteler and Bursa İnegöl, measurements were made in kitchen and hall of 50 new offices ready to sit in October 2017. The kitchens of the apartments are 10 square meters, the living room is 20 square meters, the kitchen furniture is made of 18 mm white double face coated chipboard and the flooring is made as 8 mm laminate parquet.

In this research, GANK-4 Formaldemeter device was used to determine furniture production facilities, furniture store measurements and formaldehyde emission measurements in salons and kitchens in new houses (Figure 1). Furniture production facilities, furniture store measurements and formaldehyde emission measurements in the salons and kitchens of new homes were made from the exact midpoint and 1 meter above the ground. Before each measurement of formaldehyde emissions, the humidity and temperature of the environment to be measured were measured with the Loyia H100 digital temperature and humidity meter. All measurements were made at 23 °C and 45% humidity.

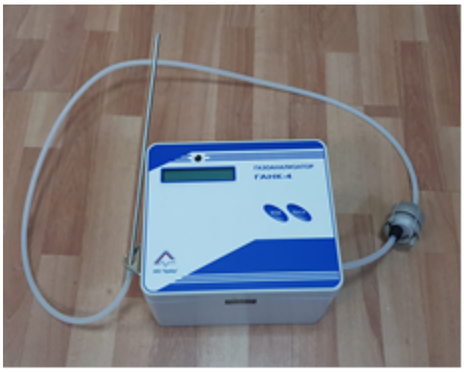

Figure 1: GANK-4 Formaldemeter device

3. Findings

3.1. Findings of Formaldehyde Emissions from Particle Boards

Formaldehyde emission value belongs to five different companies which makes production in Turkey were determined by perforator method, chamber method and gas analysis method and the results are given in Table 2.

Table 2: Formaldehyde emission values of chip board samples

Chipboard Producers	TS EN 120 Perforator Method (mg/100gr)	TS EN 717-1 Chamber Method (ppm)	TS EN 717-2 Gas Analysis Method (mg/m^2h)
A	15	0.12	3.8
B	16	0.11	3.6
C	19	0.14	3.9
D	13	0.11	3.5
E	10	0.09	3.1

According to the results in Table 2, value of 10-19 mg/100gr were obtained as a result of the perforator method measurements. While the samples according to the chamber method gave a minimum of 0.09 ppm and a maximum of 0.14 ppm, the value obtained according to the gas analysis method were determined as 3.1-3.9 mg/m2h. The results obtained from E company are the lowest result in the three measurement methods according to the other firms, while the samples taken from C company gave the highest value.

3.2. Findings of Formaldehyde Emissions in Furniture Production Sites

In furniture manufacturing sites, 20 in the Siteler region in Ankara, 20 in the Bursa İnegöl region and also 10 in Kastamonu, were measured. The values of the measurements made in Table 3 are given.

Table 3: Measured formaldehyde emission values in furniture manufacturing plants

	≤ 0.3 ppm		0.4-0.5 ppm		≥ 0.6 ppm	
	Number	%	Number	%	Number	%
Ankara	1	5	18	90	1	5
Bursa	3	15	15	75	2	10
Kastamonu	-	-	8	80	2	20
Total	4	8	41	82	5	10

According to the results in Table 3, the results of measurements made at randomly selected furniture production facilities located in the Ankara site area resulted in value of 0.4-0.5 ppm at 90% and value of 0.6 ppm and 5% at 5%. 75% of firms measured in Bursa İnegöl and 80% in Kastamonu region are between 0.4-0.5 ppm. According to all the results made in the furniture production facilities, 8% is measured as ≤ 0.3 ppm, 82% is measured as 0.4-0.5 ppm, 10% is measured as 0.6 ppm. The lowest value of 0.3 ppm and the lowest value of 15% were determined in Bursa İnegöl region.

3.3. Findings of Formaldehyde Emissions in Furniture Production Sites

In furniture stores, 20 in the Siteler region in Ankara, 20 in the Bursa İnegöl region and also 10 in Kastamonu, were measured. The mean value of the measurements made are given in Table 4.

Table 4: Measured formaldehyde emission value in furniture manufacturing plants

	≤ 0.3 ppm		0.4-0.5 ppm		≥ 0.6 ppm	
	Number	%	Number	%	Number	%
Ankara	10	50	9	45	1	5
Bursa	3	15	15	75	2	10
Kastamonu	4	40	5	50	1	10
Total	17	34	29	58	4	18

In Table 4, as a result of the measurements made at the randomly selected furniture production facilities located in the Ankara site area, 50% ≤ 0.3 ppm, 45% 0.4-0.5 ppm value are obtained, 5% Value of 6 ppm and above were obtained. 75% of the stores measured in Bursa İnegöl and 50% in the Kastamonu region are between 0.4-0.5 ppm. According to all the results in the furniture stores, 34% ≤ 0.3 ppm, 58% 0.4-0.5 ppm and 18% was measured as ≥ 0.6 ppm. In the most of furniture stores, It is stated that the customers entering the store say there is a smell in the store.

3.4. Findings of Formaldehyde Emissions in Newly Built Apartments

The value of the emission measurements made with the GANK-4 Formaldemeter are given in Table 5.

Table 5: Measured formaldehyde emission value in newly built apartments

Kastamonu	≤ 0.03 ppm		0.04-0.09 ppm		0.1-0.2 ppm		≥ 0.2 ppm	
	Number	%	Number	%	Number	%	Number	%
Kitchen	5	10	17	34	23	46	5	10
Living Room	3	6	18	36	22	44	7	14

According to the measurement results in the new apartments 10% of kitchens in apartments ≤ 0.03 ppm, 34% in 0.4-0.9 ppm, 46% in 0.1-0.2 ppm, 6% of halls ≤ 0.03 ppm, 0.4-0.9 ppm, 44% 0.1-0.2 ppm.

4. Results

In Turkey, in particle boards provided by five different manufacturers and mostly preferred in furniture production, as a result of the perforator method measurements, according to TS EN 13986 standard, the formaldehyde emission class is E2 (> 8 mg/100gr). According to the chamber method, the samples of A, B, C, D with regard to TS EN 13986 formaldehyde emission class E2 (> 0.09 ppm) and the sample E is E1 (≤ 0,09 ppm). According to the results of the gas analysis method, company samples A, B, C are of formaldehyde emission class E2 (> 3.5 mg / m2h) with regard to TS EN 13986 standard and sample E1 (≤3.5 mg/m2h) of D and E firms. According to these results, D and E companies' samples with E2 with regard to perforator method and E1 with chamber and gas analysis method.

The values determined as 8% for ≤ 0.3 ppm, 82% for 0.4-0.5 ppm and 10% for ≤ 0.6 ppm in the measurements made at the furniture manufacturing plants in Ankara Siteler, Bursa İnegöl and Kastamonu Center. In the furniture stores, in area where board panel furniture is exhibited 34% ≤ 0.3 ppm, 58% 0.4-0.5 ppm, and 10% ≥ 0.6 ppm determined. In the center of Kastamonu, measurements made in kitchens and halls of a newly built 50-apartment house, 10% of kitchens ≤ 0.03 ppm, 34% of 0.04-0.09 ppm, 46% of 0.1-0.2 ppm, 10% of ≥ 0.2 ppm, 6% of the halls are ≤ 0.03 ppm, 36% are 0.04-0.09 ppm, 44% are 0.1-0.2 ppm, 14% is ≥ 0.2 ppm are measured.

The Consumer Product Safety Commission (CPSC) has publicly declared that formaldehyde levels should normally be below 0.03 ppm in closed environments. As a result of the studies, all the measurements in furniture production facilities and furniture stores exceeded 0.03 ppm. In the results of measurements made in 50 newly built dwellings, only 6% was below 0.03 ppm.

5. Recommendations

Formaldehyde-based glues are widely used in the forest industry. Formaldehyde is a well-known indoor pollutant and affects everybody, from customer to consumer, in the indoor environment. In Europe, products are certified with Blue Angel, Ecolabel and E1 certificates and only products with formaldehyde emission class E1 are allowed to be produced and imported. In the US, products with CARB certification are certified and only products with a formaldehyde emission of 0.09 ppm are allowed.

The Turkish Standards Institute has been issuing E1 certificates since 2013.This document is not compulsory but is provided at the request of the firm. As a result of the study; the chipboards supplied from the 5 major producers in our country are above the E1 level. In addition, formaldehyde gas emission value of the furniture production area and composite panel plates, from the production process to the consumer, are considerably high.

Formaldehyde emission value determined for wood composite sheet products in our country should be more strictly controlled by the state and companies should be supervised in this regard. A standard that sets out the emission value of finished furniture products should be studied, the emission values of the products reaching the last consumer should be controlled by the government in terms of human health. In addition, the constructions on the furniture which reach the final consumer such as paint, coating reduce formaldehyde release. However; if these structures are worn out over time, the release will increase rapidly, so the supervisor to be brought must oblige E1 in the bare plate. It is important for these regulations to go into effect without losing time, in order to protect human health in the living spaces, especially for children who are our future guarantees.

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DETERMINING SYMMETRIC-ASYMMETRIC FURNITURE PREFERENCES AND FORM AND COLOUR PREFERENCES FOR CHILDREN'S ROOM OF THE GIFTED CHILDREN

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Abstract

In this study, it was aimed to determine the preferences of gifted children for symmetric-asymmetric furniture and children room's shape and colour preferences. For this purpose, a questionnaire consisting of 20 pairs of symmetric-asymmetric furniture samples and 18 different children's room designs with triangular, square and circular forms and main and intermediate colours were applied to gifted children and their preferences were determined. When the results were evaluated, the rate of symmetric furniture preference was determined to be 65%. It was also determined that the gifted children firstly pay attention to functionality in their symmetric furniture preference and make their choices accordingly and give particular importance to visual quality in asymmetric and functional designs. The most preferred model is square, followed by circle and triangle. When it comes to the colour preferences, cold colours have been determined to be the most preferred colours; blue, purple and green colours have been selected respectively. According to these results, it can be suggested that square model, cold colours and symmetric designs should be preferred for furniture designs for the gifted children.

Keywords: Furniture, Interior architecture, Gifted children, Children's room.

1. Introduction

A gifted individual is defined as an individual who learns faster compared to his or peers; is at the fore in the capacity related to creativity, art and leadership; possesses special academic skills; understands abstract ideas, likes to act independently of his or her areas of interest and performs at a high level (Bilsem, 2018). It is stated that general mental abilities of the gifted individuals differ from other children in one or more than one area such as special academic skills, creative or productive thinking ability, leadership ability, visual and artistic ability, and psychomotor ability or in harmony with the combination of these areas in terms of showing high achievement and having potential (Çağlar, 1986). The qualities that distinguish gifted children from other children are their special abilities and competence to carry out tasks at a high level. It is seen that these children need differentiated educational programs and services rather than normal school programs in order to be able to contribute to themselves and the community (Clark, 1997). Some of the researches conducted on gifted children are generally related to the social and emotional problems of children (Akarsu and Mutlu, 2017) or the difficulties that their parents face (Karakuş, 2010). In order not to face difficulties or problems because of differences in the developmental characteristics of the gifted children, it is extremely important to be aware of these characteristics and show the appropriate approach (Morawska and Sanders, 2008). Therefore, knowing the characteristics of furniture and colour preferences that gifted children will use in their living environment is considered as significant. How is the furniture form and colour preference of the gifted children who show different characteristics from their peers and have a high level of perception for their rooms? How is the symmetrical-asymmetrical furniture preference of the gifted children who show different characteristics from their peers? It is aimed to contribute to these special talents of the gifted children and support their lives under more comfortable conditions both mentally and physically by increasing their success as a result of determining these preferences and integrating them with the designs that will be made.

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2. Methods

In this study, it was aimed to determine the preferences of gifted children for symmetric-asymmetric furniture and children room's shape and colour preferences. For this purpose, a questionnaire consisting of 20 pairs of symmetric-asymmetric furniture samples and 18 different children's room designs with triangular, square and circular forms and main and intermediate colours were applied to 45 gifted children and their preferences were determined. While the questionnaires were being formed, studies of Uzun et al. (2017) and Sarıkahya et al. (2017) were used. In order to determine the preferences of gifted children for symmetric-asymmetric furniture and children room's shape and colour preferences, colourful printouts were given to the children and their preferences were determined. The data of the survey were collected in Çankırı between April and June in 2017.

3. Findings

Data related to the gender of the children who participated in the research have been given in Table 1 (f: frequency).

Table 1: Gender

Gender	f	%
Male	21	46,67
Female	24	53,33
Total	45	100

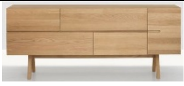
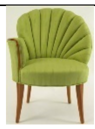
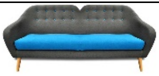
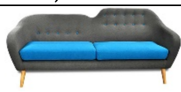
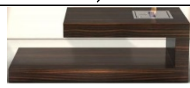
Accordingly, 53.33% of the children who participated in the research are females. The data on the age of the children who participated in the research have been given in Table 2.

Table 2: Age

Age	f	%
7-10 years	22	48,88
11-13 years	17	37,79
14-15 years	6	13,33
Total	45	100

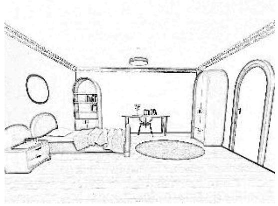
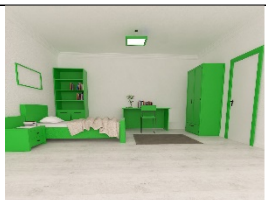
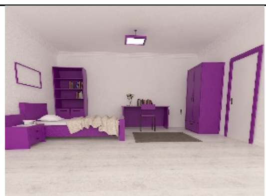
According to the table, 48.88% of the children who participated in the research are aged between 7-10 years old. Data related to the symmetrical-asymmetrical furniture preference percentages of the children have been given in Table 3.

Table 3: Symmetric – asymmetric furniture preference percentages of the children

	Symmetric	Asymmetric		Symmetric	Asymmetric
1		 (Web-1)	11		 (Web-12)
%	73,33	26,67	%	64,44	35,56
2	 (Web-2)	 (Web-3)	12		 (Web-13)
%	48,89	51,11	%	86,67	13,33
3		 (Web-4)	13		 (Web-14)
%	48,89	51,11	%	66,67	33,33
4		 (Web-5)	14		 (Web-15)
%	80	20	%	73,33	26,67
5		 (Web-6)	15		 (Web-16)
%	40	60	%	8,89	91,11
6		 (Web-7)	16		 (Web-17)
%	91,11	8,89	%	95,56	4,44
7		 (Web-8)	17		 (Web-18)
%	66,67	33,33	%	66,67	33,33
8		 (Web-9)	18		 (Web-19)
%	84,44	15,56	%	48,89	51,11
9		 (Web-10)	19		 (Web-20)
%	93,33	6,67	%	44,44	55,56
10		 (Web-11)	20	 (Web-21)	 (Web-22)
%	88,89	11,11	%	17,78	82,22

According to this, the most preferred 13 pairs is symmetrical among 20 pairs of furniture. The model and colours of the teen room used in the research have been given in Table 4.

Table 4: Models and colours used in the research

SQUARE MODEL	TRIANGLE MODEL	CIRCULAR MODEL
		
		
		
		
		
		
		

The preference rates of the models are given in Table 5.

Table 5: Preference rates of the models

Model	f	%
Square	28	62,22
Triangle	2	4,44
Circular	15	33,33
Total	45	100

According to the table, the most preferred model was the square model. Square model was followed by circular and triangular model. The most preferred colour percentages among all models have been given in Table 6.

Table 6: Percentages of the most preferred colours among all models

	f	%
Yellow	4	8,89
Red	5	11,11
Blue	15	33,33
Orange	4	8,89
Green	7	15,56
Purple	10	22,22
Total	45	100

Accordingly, the most preferred colour was blue and blue was followed by purple and green respectively. The most preferred colours of the models have given in Table 7.

Table 7: Most preferred colours of the models

		Yellow	Red	Blue	Orange	Green	Purple	Total
Square	f	4	4	10	1	4	5	28
	%	14,28	14,28	35,71	3,57	14,28	17,85	100
Triangle	f	0	0	0	1	1	0	2
	%	0	0	0	50	50	0	100
Circular	f	0	1	5	2	2	5	15
	%	0	6,67	33,33	13,33	13,33	33,33	100

Accordingly, the most preferred colours of the square model are blue and purple respectively, the most preferred colours of the triangular model are orange and green and the most preferred colours of the circular model are blue and purple. The most preferred models and colours by boys have been given in Table 8.

Table 8: The most preferred models and colours by male

Model	f	%	Yellow	Red	Blue	Orange	Green	Purple
Square	13	61,90	0	3	5	1	4	0
			0	23,07	38,46	7,69	30,76	0
Circular	8	38,10	0	1	2	2	2	1
			0	12,5	25	25	25	12,5
	21	100						

According to this, 61.90% of 21 male students preferred square model and 38.10% preferred circular model. 38,46% of those who preferred the square model preferred blue colour, 25% of those who preferred the circular model preferred blue, orange and green colours. The most preferred models and colours for girls have been given in Table 9.

Table 9: The most preferred models and colours by female

	f	%	Yellow	Red	Blue	Orange	Green	Purple
Square	15	62,5	4	1	5	0	0	5
			26,67	6,67	33,33	0	0	33,33
Triangle	2	8,33	0	0	0	1	1	0
			0	0	0	50	50	0
Circular	7	29,17	0	0	3	0	0	4
			0	0	42,85	0	0	57,15
	24	100						

According to this, 62.5% of 24 female students preferred square model, 29.17% preferred circular model and 8.33% preferred the triangular model. 33.33% of those who preferred square model preferred blue and purple colours, 57.15% of those who preferred circular model preferred purple and 50% of those who preferred the triangular model preferred orange and green colours.

4. Conclusion and Discussion

When the results of the research were analysed, it was determined that the preference rate of symmetrical furniture was 65% while the preference rate of asymmetrical furniture was 35%. Sarıkahya et al. (2017) in their study which was conducted on subjects that have average intelligence related to the preferability of asymmetrical furniture found that the most preferred 12 pairs of furniture were asymmetric among 20 pairs of furniture. In other words, the preference rate of asymmetrically designed furniture was 60% (Sarıkahya et al., 2017). Accordingly, it can be said that gifted children mostly prefer symmetrical designs.

According to this study, the most preferred forms are square, circle and triangle. According to the study conducted by Uzun et al. on subjects that have average intelligence, the most preferred form was found to be square with 54.5% which was followed by circular form with 33% and forms which were created based on triangle with 12.5%. It was determined that the gifted subjects and normal subjects had similarities with respect to form preferences and that the most preferred form was square.

According to this study, the most preferred colours of the square model are blue and purple respectively, the most preferred colours for the triangular model are orange and green and the most preferred colours for the circular model are blue and purple. According to the study by Uzun et al. (2017), the most preferred colour for the form which was created based on square is blue, the most preferred colour for triangular forms is purple and the most preferred colour for the circular forms is blue. Blue is the most preferred colour for square and circular forms. Blue brings contentment, good faith, compassion, outspokenness, honesty, flexibility, tendermindedness, agreement, reconciliation, cooperation and peace to mind (Martel, 1995). According to gifted children institute (Web-23), gifted children tend to think flexible; therefore, it is considered that gifted children may like furniture designs which have blue colour or its shades as the blue colour brings flexibility to mind.

It was determined that gifted children firstly pay attention to functionality in their symmetrical furniture preferences and they make their choices accordingly; they attach importance to visuality in asymmetrical and functional designs. Accordingly, it has been proven once again that the gifted children go directly to the target in their preferences, and their perceptions are very high.

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THE IMPACT OF SANDING SYSTEM ON THE SURFACE ROUGHNESS OF MEDIUM DENSITY FIBREBOARD

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Abstract

This paper examines the impact of the sanding system on automatic sanding machine in real production conditions on the surface roughness of medium density fibreboard (MDF). The surface of samples was egalized by sanding on wide–belt sanding machine using P80 grit sanding belt. Afterwards, the samples were sanded on the 4 aggregate automatic sanding machine at sanding speed of 14 m/s in a two-step process with the following sanding belt grits: P120+P150 and P120+P180, using two conveyor speeds: 8 and 12 m/min. In the first stage of sanding, the samples were sanded by narrow belt aggregate, with sanding direction perpendicular towards the processing direction of sample in sanding machine. The second stage of sanding was conducted on the wide-belt aggregate, with sanding direction parallel towards the processing direction of sample in sanding machine. The surface roughness was measured by the contact-mechanical gauge and expressed by parameters R_a, R_z and R_t. As expected, results confirmed that sanding belt grit in the last stage of sanding had significant effect on the surface roughness of MDF. On the other hand, variation of speed of conveyor did not affect the surface roughness of MDF, for both combinations of sanding belt grits.

Keywords: MDF, Sanding, Surface roughness, Sanding belt grit, Speed of conveyor

1. Introduction

Most often sanding is the first operation in the technological process of surface finishing of wood and wood-based products. Nowadays, the sanding of flat panels is usually done on the automatic sanding machines in several following steps (stages), ensuring gradual removal of the irregularities on the surface and thus achieving the minimum required roughness and uniform quality of the surface on the entire panel. The uniform roughness of the surface layer of the substrate is a prerequisite for the quality surface finishing of the wood and wood-based products. Most of the defects in the surface layer of the substrate become apparent after the application of the surface treatment material (coatings, etc.). In those cases, the correction of the transferred defects from the substrate, often involves total removal of the material surface layer to the raw substrate. Any additional step in technological process of wood surface finishing means additional costs, in regards to processing time and cost of materials. Those costs are enlarged by the costs of the re-processing of the substrate after total removal of the film coating with defects. Therefore, it is necessary to pay special attention to the selection of the optimal sanding program, according to the type of substrate and type of finishing material, but also in regards to the further purpose of the finished product.

The surface roughness of wood products is depending on many factors related both to wood properties and wood working operational parameters (Gurau et al. 2007; Magoss E. 2008). It is known that during sanding the processing roughness of the wood surface is affected by number of factors: grit-size of sanding belts (Ratnasingam et al. 2002; Saloni et al. 2005; Hendarto et al. 2006; Kilic et al. 2006; de Moura and Hernández 2006; Salcă and Hiziroglu 2012; Varasquim et al. 2012; de Sampaio Alves et al. 2015; Laina et al. 2017), sanding speed (de Moura and Hernández 2006; Varasquim et al. 2012), speed of the conveyor (Ratnasingam et al. 2002; de Moura and Hernández 2006; Škaljić et al. 2009; Salcă and Hiziroglu 2012), type of abrasive material (Ratnasingam et al. 2002; Saloni et al. 2005; de Moura and Hernández 2006), direction of sanding, sanding pressure (Saloni et al. 2005; Varasquim et al. 2012), operating time of the sanding belt

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(Ratnasingam et al. 2002; Palija et al. 2014), hardness of the rubber contact roller (Ratnasingam et al. 2002) etc.

Medium density fiberfboard (MDF) is an engineering product obtained by hot-pressing of fine glued wood fibers at certain regimes (temperature, pressure and time). Due to lower impact of irregularities that are result of anatomical structure of pressed fibers, initial surface roughness of MDF is generally lower in comparison to surface roughness of wood. It is assumed that the factors that affect the roughness of the wood during sanding will affect the roughness of the MDF as well. Previous research confirmed that surface roughness of sanded MDF is affected by: grit-size of sanding belts (Kiliç et al. 2009; Ayrilmis et al. 2010); sanding speed and feed speed (WILKOWSKI et al. 2015), fibers wood species (Gurau et al. 2017), fineness of wood fibers and relative humidity of exposure (Ozdemir et al. 2009).

This research examines the technological process of the surface preparation of MDF in real production conditions. The aim of this paper was to determine the optimal sanding program of MDF in terms of the grit of the sanding belts in the two-stage process and the speed of conveyor belt, expressed by the lowest surface roughness of MDF.

2. Materials and Methods

For this research 12 samples of the commercially manufactured MDF dimensions: 750x300x4 mm, were used. To ensure a safe passage through the sanding machine, MDF samples were glued to calibrated 34 mm-thick blind frame. Surface preparation of MDF carried out in real production conditions on automatic sanding machines. Calibration of the glued MDF samples was done on the wide–belt sanding machine with contact rubber roller (model LMF 1300 RRRR, manufacturer Egurko-Ortza), using 80-grit sanding paper. After calibration, fine sanding of samples was carried out on the 4 aggregate wide-belt sanding machine (model Rita 4CT EL, manufacturer Viet): first aggregate with narrow sanding belt and following aggregates with wide sanding belt. All sanding aggregates were equipped with flat sanding platen. The calibrated samples were divided into 4 group, according to program of fine sanding of MDF surface (Table 1). Each group consisted of 3 samples. During sanding the sanding speed was set constant: 14 m/s, while conveyor speed was varied. One half of all samples was sanded at 8 m/min conveyor speed, while the other half was sanded at conveyor speed of 12 m/min. The indicated speed of sanding and speeds of conveyor were in accordance with the recommendations of the sanding belt manufacturer for sanding of MDF and other wood-based panels (Web-1). Sanding was conducted in two-step process by activation of the first and second aggregate. In first step sanding was conducted perpendicular to the processing direction of sample in sanding machine, while in second step sanding was parallel to the processing direction of sample. This combination of sanding directions enables the raising of the wood fibers from the surface in first step and its removal in the following step. Sanding was carried out using two combinations of grits of the sanding belts: P120+P150 and P120+P180. The sanding pressure was 0.5 bar.

Table 1: Groups of samples

Group of samples	**I**	**II**	**III**	**IV**
Gritof sanding belt	P120+P150		P120+P180	
Speed of conveyor (m/min)	8	12	8	12

After sanding, surface roughness of the sample was determined by measuring the roughness parameters: R_a, R_z and R_t, in accordance with standard ISO 4287:1997. The measurement of surface roughness was carried out by stylus contact tester (model TimeSurf TR200, manufacturer Beijing TIME High Technology Ltd.), Figure 1. The diameter of the diamond stylus tip was 2 μm, and the stylus was pressed on the surface by the force of 4 mN. Reference length was 2.5 mm, which is in accordance with the recommendation of the standard ISO 4288: 1996. Measurements were made perpendicular to the direction of of the movement of the samples in the machine (perpendicular to the final sanding step). 6 measurements of surface roughness parameters were measured for each sample, which make total of 72 measurements (6x3x4).

Figure 1: Measurement of surafece roughness parameters of MDF by stylius contact tester

3. Results

Table 2 shows the results of surface roughness of sanded MDF according to the groups of samples.

Table 2: Surface roughness of sanded MDF for different conveyor speed and combination of sanding belt grits

	Group of samples			
Surface roughness parameter (µm)	***I***	***II***	***III***	***IV***
R_a	7.091 (1.03)	7.787 (1.79)	5.327 (0.54)	5.719 (0.71)
R_z	48.50 (6.36)	51.45 (8.92)	37.86 (4.02)	40.13 (5.14)
R_t	65.30 (12.13)	65.57 (22.04)	49.02 (7.67)	52.22 (9.29)

Values of standard deviation are written in parentheses

‘ The use of lower conveyor speed (u = 8 m/min) resulted in lower surface roughness of MDF samples in comparison to the use of higher conveyor speed (u = 12 m/min), for both combinations of sanding bet grits: P120+P150 and P120+P180. In addition to lower values of surface roughness parameters, values of the standard deviation were lower for the samples that were sanded at lower feed, in comparison to samples sanded at higher feed speed and with same grits of sanding papers. These results can be explained by the longer contact of the abrasive grains and the surface layer of the panel at lower conveyor speed, which contributed to more uniformity and lower roughness of the surface substrate. These results are in line with finding of paper on quality of sanded surfaces of sugar maple wood, where increasing feed speed led to rougher surfaces due to higher fibrillation of cell walls in surface layer of wood (de Moura and Hernández 2006). Increasing the feed speed (from 6 to 18 m/min) during sanding of black alder led to general increase of the processing roughness expressed by the R_k (Salcă and Hiziroglu 2012).

Along with sanding, the increase of the conveyor speed in other working processes leads to higher surface roughness of wood and wood-based substrate. Thus the increase of feed rate (from 6 to 24 m/min) during planning of beech, oak and fir wood resulted in the increase of R_a (Škaljić et al. 2009). In the research of surface roughness aspects in milling of MDF, it was found that as the speed of the conveyor increased (from 0.5 to 5 m/min), the roughness parameters: R_a, R_z and R_t increased (Davim et al. 2009). Sanding of MDF at constant rotational spindle speed (n = 8000 rpm) showed tendency to increase of surface roughness with increase of feed per revolution (WILKOWSKI et al. 2015).

On the other hand, the results of the independent t-test (for P120+P150: t = (27.157) = - 1.427, p = 0.163 for R_a; t = (34) = - 1.144, p = 0.261 for R_z; t = (26.426) = - 0.045, p = 0.964 for R_t and for P120+P180: t = (34) = - 1.873, p = 0.07 for R_a; t = (34) = - 1.478, p = 0.149 for R_z; t = (34) = - 1.129, p = 0.267 for R_t) showed that there is no statistically significant difference between the surface roughness parameter: R_a, R_z, and R_t for different speed of the conveyor belt, for both combinations of the sanding belt grits .

Due to the absence of the statistically significant differences in surface roughness of MDF samples sanded at different conveyor speeds, the results of surface roughness parameters were further analyzed independently of the conveyor speed, Table 3. When comparing the surface roughness of sanded MDF samples using two combinations of the sanding belt grits, it is clear that the use of smaller abrasive grains in the final step of sanding resulted in the lower surface roughness expressed by all three roughness parameters (R_a, R_z, R_t). The results of independent t-test confirmed that the difference in values of all three observed roughness parameters for two combinations of the sanding belt grits was statistically significant (t(43.650)=-6.717, p≤0.05 for R_a, t(50.418)=-6.804, p≤0.05 for R_z and t(48.257)=-4.728, p≤0.05 for R_t), This results were expected since sandpaper with higher grit size contains finer abrasive thus produces finer sanded surface (Tan et al. 2010).

Table 3: Surface roughness of sanded MDF for different combination of the sanding belt grits

Surface roughness parameter (μm)	***Grit of sanding paper***		Decrease of roughness (%)
	120+150	120+180	
R_a	7.439 (1.48)	5.523 (0.65)	25.76
R_z	49.97 (7.78)	38.99 (4.69)	21.97
R_t	65.44 (17.54)	50.62 (8.55)	22.65

Values of standard deviation are written in parentheses

In the research of the impact of sanding of MDF panels made from R. ponticum wood using P60 + P80 + P120 sanding bets (Ayrilmis et al., 2010), values of surface roughness parameters (R_a = 4.15μm, R_z = 30.76μm and R_t = 38.60 μm) were lower in comparison to values of surface roughness parameters that were obtained in our research, when using higher grits of sanding paper in final stage (P150 or P180). This disagreement confirms that the surface roughness of MDF is affected by characteristics of the raw materials used in production, production conditions and machining characteristics (Kiliç et al. 2009). Thus in support of that, after sanding of MDF made of thermally treated rubberwood fibers, with P120 and P150 grit sanding belts, values of surface roughness parameters (R_a = 6.93 μm, R_z = 41.15μm and R_t = 52.08 μm) were slightly lower than the values obtained in this study, which can be explained by type of fibers, thermal treatment of fibers and pressing regimes (Jarusombuti et al., 2010).

The values of surface roughness parameters of MDF sanded with P100 and P150 grit sanding paper in previous research (Ozdemir, Hiziroglu and Malkocoglu 2009) were lower in comparison with results that we obtained (R_a = 2.04 μm, R_z = 19.57μm and R_t = 23.73 μm, for samples made from unrefined fibers and exposed to 65% of relative humidity). This deviation can be related to the direction of sanding, since in mentioned research sanding was performed parallel to direction of the movement of the samples on the conveyor through the machine. In our research, the sanding was done perpendicular to the feed direction in the first step, and then parallel to the feed direction in second step. The combination of the perpendicular and parallel sanding in relation to the movement of the samples is recommendation for effective removal of wood fibers from the surface of the panel. In addition, prior to fine sanding, an equalization using 80grit sanding paper was carried out. According to the data of the sanding belt manufacturers, the size of grains of 80 grit sanding paper average about 200 μm. Knowing that the surface layer of MDF is compact, the use of 80 grit sanding paper in calibration of MDF had created scratches that was too depth for removal by subsequent higher grit sanding belts, resulting in higher values of surface roughness.

According to the data obtained from the practice, the value of parameter R_a of sanded wood samples is approximately 5 times lower than the parameter R_z, and the value parameter R_z is approximately 1.6 times lower than the parameter R_{max} (Janković, 1975). The ratio of parameters R_z to R_a of MDF samples sanded at different systems (P60; P60 + P80 and P60 + P80 + P120) ranged from 6.56 to 7.41(Ayrilmis et al. 2010), while the ratio of R_t and R_z varied from 1.24 to 1.25. The ratio R_z: R_a for sanded MDF samples in this research was 6.72 and 7.02 for sanding grits P120+P150 and P120+P180, respectively. The higher ratio of R_z to R_a in samples of MDF can be associated with a more compact structure of MDF, where the proportion of valleys of is smaller compared to the valleys in surface layer of sanded wood that are the result not only of sanding process, but also of structural roughness of wood surface. The ratio of R_t: R_z for sanded MDF in this research was 1.30 for P120+P150 and 1.31 for P120+P180. Similar values of R_z and R_t (lower ratio) indicate constant surface irregularities, while significant difference between them indicates a surface defect in an otherwise constant surface (Web-2). Thus, the lower ratio of R_t to R_z in MDF in relation to wood can be explained by the compact initial MDF structure prior to the sanding. The use of smaller abrasive grains in final stage of sanding created higher deviation between the average surface roughness and the maximum height of peak to valley (8.80 for sanding grits P120+P150 and 9.17 for sanding grits P120+P180).

Although all of measured parameters of surface roughness decreased when using P180 grit sanding paper, instead of P150 grit sanding paper in final stage of sanding, the largest change was in value of R_a parameter (25.8 %). Based on these results, the surface roughness parameter R_a can be recommended to be used for basic evaluation of surface roughness of MDF. For further research, it is necessary to include additional combinations of sanding papers grits to determine the most sensitive parameter for characterization of surface roughness of MDF after sanding.

4. Conclusion

Based on the results of this research, the following can be concluded:

- The increase of conveyor speed during sanding (from 8 to 12 m/min) did not led to statistically significant increase of surface roughness parameters, R_a, R_z and R_t.
- The lower surface roughness of MDF, expressed by R_a, R_z and R_t was achieved when using P120+P180 sanding grit sequence in comparison to P120+P150. In respect to these findings, the use of the higher speed of the conveyer and higher sanding grit in final sanding step is recommended. This proposed system ensures higher productivity of the sanding process without reducing the quality of the sanding process in term of the surface roughness. This recommendation should be related to the final use of the MDF and the properties of the material that would be applied on its surface in the following step.

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INVESTIGATIONS ON WOOD DESTROYING MARINE BORERS IN THE TURKISH COASTAL WATERS

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Abstract

Wood is used in the marine environment for several purposes such as groynes, wharves, jetties, dolphins, and navigational posts. It is also important material in the boat construction in many countries due to the wide availability, ease of fabrication, repair and maintenance, strength and elasticity properties. In the marine environment, wood is susceptible to attack and deterioration by marine wood-borers. Temperature and salinity of the seawater influence the distribution of wood-boring organisms. Most studies on wood durability in the marine environment involved in using of tropical timbers as well as wood preservatives or modified wood in different test sites in the world. Although Turkey is surrounded on three sides by the sea, less attention has been given to the marine borers and protection of wood in the marine conditions. The existence of *Teredo navalis* (shipworm) in the deep waters of Marmara was reported by early investigations. *T. navalis* was also found to be dominant species in the Western part of the Black Sea, heavily destroyed the Scots pine samples in one year. Investigations revealed that CCA and creosote shoved resistance to marine borers while the performance of copper azole was promising in the Black Sea. From the tropical wood species, wenge, douka, azobe and paduk showed great resistance to marine borers in the Turkish coastlines. Test sites in Trabzon, Ereğli and İskenderun exhibited the highest boring activity in comparison to the other test locations. *Bankia carinata*, *Nototeredo norvagica*, *Teredo navalis*, *Lyrodus pedicellatus* and *Limnoria tripunctata* were found in the wood samples in the Southern coasts of the Turkey. *Teredothyra dominicensis* was identified as an invasive species in the coast of Kaş in Antalya. DNA barcoding study proved that there was no difference in the barcodes of *N. norvagica* collected from the Atlantic and the Mediterranean Sea.

Keywords: Marine wood-borers, Teredinids, Limnoriids, Turkish coastal waters

1. Introduction

Wood material has been used for centuries to meet the needs of human beings. Because, wood has unique characteristics compared to alternative materials such as renewability, the aesthetic appearance, its performance from past to today, the design and flexibility in use and manufacturing, easy repair and maintenance, high strength and elasticity under load.

Due to the wide availability and easy of fabrication and repair, wood has been the main resource used in the construction of rafts, boats, ships and maritime structures (Borges 2014a; Cragg et al., 2001). Liphschitz and Pulak (2007) investigated the identification of wood species used in ancient shipbuilding in the Eastern Mediterranean. Lebanese cedar, Calabrian pine, Corsica pine and Turkey oak were the main wood species used in wooden shipbuilding in their report.

In the marine environment, wooden materials are susceptible to attack by wood borers. Although microorganisms decay the surface of wood in the sea water, marine borers molluscs and crustaceans are the cause of the wood destruction. The superficial decay of microorganisms accelerates the settlement of marine borers on the wood surface (Eaton 1985). The boring organisms include Bivalvia (Teredinidae and Pholadidae), Isopoda (Limnoriidae and Sphaeromatidae), and Amphipoda (Cheluridae).

Wood is generally impregnated with preservatives or tropical species is used against marine borers, another alternative is the using of physical barriers. Impregnation of wood with creosote or chromated copper arsenate provided resistance to marine borers and this application was found economically viable. However, such these traditional preservatives have been limited by European Commission (2003) in marine structures due to the environmental concerns. Naturally durable timbers from tropics are widely used in marine structures, but a few species particularly have a high demand because of their reputation in this field. For example, tropical species such as turpentine and greenheart shows resistance against teredinids are not immune to attack by limnoriids (Borges et al., 2008).

Wood-boring organisms cause economic damage to the structures such as wharves, piers, groynes, lock gates, house stilts and other facilities used in the marine (Cragg et al., 1999). The damage to submerged coastal structures was estimated to be $1 billion annually in the USA, and crustacean borers was mainly shown as responsible for this cost (Boyle 1988). Estimated economic loss was reported to be ranged from 300 to 3000 million Rs. annually due to the wood borers in India (Karande and Chongdar 2001). The cost of damage by limnoriids has been estimated to be of the order of billions of Euros worldwide (Borges et al., 2014b).

Marine borers are also a major threat to the cultural heritage under water. For example, shipworm, *Teredo navalis* can cause great destruction to wooden archaeological remains in the marine environment. (Eriksen et al., 2016).

The activity of marine wood-borers is still of great concern in Europe. Several factors including climatic change, physiological and ecological mechanisms probably have an effect on the increasing of the wood-borer attack. For this purpose, an exploratory workshop on "Marine wood borers: new frontiers for European waters" was held in Venice in 2013. The main output of this workshop was to establish a research network that coordinates scientists with a global perspective, to create new research areas on wood-boring organisms and to cooperation in the future (Tagliapietra et al., 2013).

The aim of this paper is to introduce marine wood-borers, take attention to the destructive effect of these organisms in wooden structures, and present investigations performed in the Turkish waters.

2. Marine Wood-Borers

There are four kinds of wood-boring organisms living in the sea, two of which are crustaceans and the other two are molluscs. The destruction of wood in the sea is mainly carried out by wood-boring molluscs and crustaceans and their diagnostic methods are given by Turner (1971a) and Kühne (1971).

2.1. Molluscs

The molluscs comprise the species belonging to teredinids and pholads. Although the teredinids are widespread throughout the world, the distribution of pholads is limited and live in temperate and salty tropical waters (Eaton 1985).

Teredinids or shipworms are bivalve molluscs and Lyrodus, Bankia, Teredo and Nausitora are known the members of Teredinids. Teredinids can attack wood from mud-line to mid-tide, but the most severe attack is near the mud-line. The shell in these organisms is small and covers the front of the animal act as a rasp in the boring of wood. Teredinids release microscopic larvae in the sea water, become active between 1 and 30 days depending on the development stage and can grow up to two meters in length (Cookson 1986). Most of the teredinids are grown feeding in the wood and at the same time filter feed. Cellulolytic nitrogen-fixing bacteria were also isolated from teredinids (Waterbury et al., 1983). Distribution of the larvae can take place by the way of currents or ballast water in the ship. Even, the adults of *T. navalis* can be spread by driftwood (MacIntosh et al., 2012).

If the larvae settle on a substrate like untreated wood, begin to bore for entry holes. These holes on the wood are hardly visible since the larvae are too small. Therefore, the surface of the wood may appear sound but the interior is riddled. After settlement, a larva develops in to adult form, wormlike in the burrow where the calcareous substance secreted by the borer is deposited. Shipworms contain a pair of siphons and a pair of calcified pallets at the posterior of the body. The function of the siphons is the intake of seawater and the expulsion of the waste while the pallets close off the burrow to protect the borer from the predators. The structure of the pallet is of great importance due to the identification of the species (Johnson 1986).

Another group of molluscs is the pholad, destroying wood in the sea and *Martesia striata* L., is the most well-known species, which causes significant damage in the wood. *M. striata* live in tropical and subtropical waters with high salinity, and is fed by filtering the water like Sphaeroma species. They do not feed with wood, only burrow wood and produce pear-shaped tunnels (Turner and Johnson 1971). Pholads are not as destructive as teredinids for some reasons such as less widely distributed, have no ability to close off burrows by their pallets and do not burrow deeply (Johnson 1986).

Researches on marine trials stated that the increase in temperature in the sea water led to an increase in the numbers and activities of marine wood-borers. In addition, another factor that affects the distribution of marine wood-borers is the salinity in the sea water (Turner 1971b).

2.2. Crustaceans

The most important species of wood-boring crustaceans are Limnoria, Sphaeroma and Chelura. While Limnoria species spread throughout the world from cold water to warm water, Sphaeroma live in mild salty water. The diagnosis of these organisms is made on the basis of their external morphological characteristics (Eaton 1985).

Limnoria are from small crustaceans, 1-4 mm in length, and borrow the wood for feeding. They are from the group of invertebrates and degrade the cellulose in wood without the aid of any microorganisms since they produce own cellulase enzyme. They form small ventilation holes in the longitudinal direction in borrows, close the wood surface. Limnoria can attack wood anywhere from mud-line to mid-tide, rarely seen in the areas where the salinity is below 25 parts per thousand. Important species of Limnoria are *L.tripunctata*, *L.quadripunctata* Holthuis and *L. indica* Becker and Kampf. *L.tripunctata* Menzies is a widely studied species of limnoriid in the world (Barnacle et al., 1983).

Sphaeroma species are from crustaceans, larger than Limnoria, and can grow up to 8-14 mm in length. Among these species, three important wood-boring are *S.terebrans* Bate, *S.quoyanum* Milne Edwards and *S. Treste* Heller. Sphaeroma species can tunnel in the wood, sandstone, weak concrete and polystyrene materials. The cavities are small and in the same direction with the surface. Sphaeroma species produce an appearance like hourglass in the destruction of the wooden poles, can destroy wood in the waters where the salinities ranging from 10 to 35 parts per thousand (Cookson 1986).

Sphaeroma species are fed by filtering the seawater. They burrow wood, but do not feed with wood. However, the data obtained from the laboratory feeding experiment showed that *S. terebrans* had the ability to use the wood as food source. *S. terebrans* is widespread in tropical and subtropical estuarine waters and may burrows in cypress, cedar, palm, and pine (Benson et al., 1999).

Three species of chelurids *Chelura terebrans*, *Chelura insulae* and *Chelura brevicauda* were introduced by Kühne (1971). From these species, *C. terebrans* shows worldwide distribution in temperate and subtropical regions. Chelura attack is usually associated with limnoria in the maritime timbers in which chelura generally occupies the outer region whereas limnoria is found interior of the wood. The chelurids have less tolerance than limnoriids with regard to environmental change such as low salinity or low-oxygen conditions. Thus, the chelurids are the least important of the crustacean borers (Eaton and Hale 1993).

3. Test Method and Evaluation in The Marine Trials

For the marine exposure, Scots pine (*Pinus sylvestris*) is used as a reference sample. Wood samples are prepared to 25 × 75× 200 mm in size according to the EN 275 standard (1992). Wood is drilled on the center to a connection hole of 25 mm diameter. At least 5 replicates samples are used for each protection system and test site, and also 5 for control. Full-cell process is required for the samples to be impregnated.

The test specimens should be deployed within 6 meters below the waterline into a medium height. The samples should be inspected every year for a five-year testing period. Assessment of the samples is carried out based on the X-ray inspection and visual evaluation. In the X-ray inspection, each sample is rated according to damage by marine borer attack from 0 to 4. In this system, zero (0) indicates no attack, 1 little damage, 2 moderate damage, 3 severe destruction and 4 means complete destruction.

4. Marine Trials in The Turkish Waters

First investigation was held in the Marmara Sea where *T. navalis* was identified in Turkey (Demir 1954). Berkel reported that maritime structures around Istanbul was destroyed by teredinids in a short period. Sekendiz (1981), examined the *T.navalis* damage in the Black Sea and drew attention to the presence in the Turkish waters.

In the earlier times, a considerable study was conducted by Pınar (1997), covering the test sites in the Black Sea, Marmara, Aegean and the Mediterranean Sea in 1968. Test sites were selected in Amasra, Istanbul, Çanakkale, İzmir and Mersin where the test material exposed to marine borers for 12 months. Observations on the untreated black pine panels revealed that *Noroteredo norvagica*, *Limnoria tripunctata* and *Chelura terebrans* were the identified species. The activities of these organisms were found to be very high in all test stations except İzmir. The activity of *T. navalis* in Amasra and *L. tripunctata* in Mersin were found to be more active.

Effectiveness of the creosote and CCB (Copper, chrome, Boron) wood preservatives against marine borers by using Scots pine, fir, beech and oak wood species was studied by Bobat (1994). Control and impregnated samples were left at the test stations located in İzmit (Derince) and Mersin (Erdemli) and in Trabzon port for 14 months. At the end of the marine trial, it was determined that the samples in the Marmara Sea were not destroyed. Control samples excluding oak wood in the Mediterranean and the Black Sea were totally destroyed by marine wood-borers, while oak control specimens were found more durable than the others. A few molluscs were seen in the Scots pine and oak samples impregnated with CCB in the Mediterranean and the Black Sea, and the best results was obtained by the creosote treated samples. In the control samples exposed to the Mediterranean Sea, marine wood-borers *Lyrodus pedicellatus*, *Teredo utriculus* and *Bankia carinata* were recorded, while in the Black Sea only *T. navalis* was encountered in the control samples.

Scots pine sapwood and heartwood, oak and chestnut samples impregnated with CCA were tested in the Black Sea (Amasra) for twelve months. A heavy attack of *T. navalis* occurred in the Scots pine control panels. However, CCA treated Scots pine samples showed great resistance to marine borers, while treated samples of oak and chestnut were moderately attacked. In addition, dynamic MOE measurement indicated good correlation between untreated wood and treated wood in the assessment of borers attack (Sivrikaya et al., 2012).

Copper azole wood preservative, free of chromium and arsenic, was performed against marine borers in Amasra for 7 and 14 months intervals. *T. navalis* has been the only species, as it was in the earlier study, identified on wood panels. No damage was observed on the impregnated Scots pine and fir samples except for a few specimens at the end of 7 and 14 months exposure period. All control panels were attacked heavily, while moderate attack was seen on the black pine impregnated panels (Sivrikaya et al., 2016).

Industrial wood species used in wood yacht, boat and harbour constructions have been tested against wood-boring organisms in the Mediterranean Sea. In this context, Scots pine, oak and chestnut species were exposed to marine conditions over five months in Erdemli. During the study, the activity of teredinids was found to be very high and the most damage was observed in Scots pine sapwood and heartwood panels and followed by oak and chestnut respectively (Figure 1). Approximately half of the identified teredinids were *T. navalis*, one-fourth were *B. carinata* and the other one-fourth were *N. norvagica*. From crustaceans, chelura sp., economically less important than other species, found only in the chestnut panels (Sivrikaya et al., 2009).

Figure 1. Scots pine sapwood (a), Scots pine heartwood (b), Oak heartwood (c), Chestnut heartwood (d)

A comprehensive study was carried out by Şen et al. (2009) in the Turkish waters covering the Black Sea, Mediterranean, Aegean and Marmara Sea, determining the performance of 18 wood species from Europe and 15 from tropical woods against marine borers for 14 months. From the European species hornbeam, elm, Austrian pine, Scots pine (*Pinus sylvestris*), ash (*Fraxinus excelsior*), beech (*Fagus orientalis*) alder (*Alnus glutinosa*) and fir (*Abies nordmanniana*) were severely attacked by marine borers while olive wood samples were slightly damaged. Tropical species such as wenge (*Millettia laurentii*), douka (*Tieghemella heckelii*), azobe (*Lophira alata*) and paduk (*Pterocarpus soyauxii*) showed high resistance to boring organisms. From the commercial ports, Trabzon, Ereğli and İskenderun showed the highest boring attack. However, slight attack was shown in the marinas of Bandırma, Alaçatı and Finike. In overall experiments, 5 wood-boring organism species and 26 fouling species were identified. When compared to test stations, *T. navalis* and *L. pedicellatus* were exist in all test sites, whereas *N. norvagica* was only found only in Trabzon and İskenderun ports and *B. carinata* only in İskenderun port. From the crustaceans, *L. tripunctata* was only identified in the test sites in Finike and İskenderun (Şen et al., 2010).

To draw attention to the destruction of wooden shipwreck under water, the replica of the historical Uluburun (III) shipwreck was built, made of *Pinus brutia* including sapwood and heartwood, and deliberately sunk in the Kaş in the Eastern Mediterranean Sea in 2006. Neither wood preservatives nor surface protection was applied in the building of the replica. The degradation of the shipwreck was monitored by several dives throughout four years. The survey revealed that the hull planks and other wooden parts and frames were heavily destructed by shipworms at the end of the October 2009. The complete destruction took place in August 2010. The only remaining parts of the wreck were the mast, frame and keel, found scattered along the seabed. The obtained shipworms from the wreck concluded that the ship was infested by *N. norvagica* and *Teredothyra dominicensis*. *T. dominicensis* was the dominant species representing 92% of the shipworms collected, has previously never been reported in the Mediterranean Sea before. This wood borer was previously reported in the Caribbean Sea and The Gulf of Mexico (Shipway et al., 2010).

Identification of wood-boring teredinids according to their morphological characteristics is quite difficult. Because, the shell morphology of teredinids shows high intra-species variability, so their diagnosis is made according to the palette morphology.

To obtain precise result, Borges et al. (2012) conducted a research in which morphological evidence and mitochondrial and DNA sequences were combined to obtain a taxonomic solution in some species of teredinids. Specimens were collected in France from three areas, from Erdemli in Turkey, and the other specimens were obtained from a shipwreck site in Kaş, Turkey. According to obtained results, DNA barcodes of Atlantic and Mediterranean populations of *L. pedicellatus* diverged by 20% indicated the cryptic species. The low intra-species divergence in barcodes of *N. norvagica* specimens suggests that the Atlantic and Mediterranean forms are the same species. *T. dominicensis* was detected for the first time in the Mediterranean, and it was reported that this was the same species found in the Caribbean Sea. It was also mentioned that *B. carinata* from the Mediterranean and Caribbean may indicate cryptic species.

In addition, first occurrences of the warm-water shipworm *Teredo bartschi*, collected from Mersin, Turkey, and Olhão, Portugal was examined. It was estimated that this species found in Mersin came by rafting from the Red Sea along the Suez Canal. This was the first time that the existence of this species in the Mediterranean and the North East Atlantic was reported by Borges et al. (2014c).

Recently, biogeographic distribution of marine wood-borers in Europe has been conducted by the scientists from Eurolag and European network. Scots pine panels were exposed simultaneously in lagoons, estuaries and harbours. Experiments were carried out in 21 sites spread over 13 Countries, covering from the South Mediterranean to the Baltic and from the Black Sea to the Atlantic Ocean. Zonguldak port in Western part of the Black Sea was one of the test sites where wood borer *T. navalis* only identified. This result has confirmed again the domination of this species in the Black Sea (Guarneri et al., 2018).

5. Conclusion

Turkey is surrounded by the sea on three sides and wood is used for boat and yacht building and for various purposes such as construction of piers and docks. Marine borers either molluscs or crustaceans are the main biological hazards for wood in the marine environment. In addition, invasive species, originating from the other parts of the world increase the biodiversity and also threat to the facilities or materials, even cultural heritage made of wood under the sea water.

Therefore, more attention should be paid to the presence of marine wood-borers and distribution of them in the Turkish waters. On the other hand, researches are needed to develop novel protection methods, environmentally friendly, against marine wood-borers.

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