WOOD RESEARCH
59 (2): 2014
297-302

THE INFLUENCE OF FIT ON THE DISTRIBUTION OF GLUE IN OVAL TENON/MORTISE JOINT

Igor Džinčić
University of Belgrade, Faculty of Forestry, Department for Wood Processing
Belgrade, Serbia

Dragan Živanić
University of Novi Sad, Faculty of Technical Sciences
Department for Mechanization and Design Engineering
Novi Sad, Serbia

(Received July 2013)

ABSTRACT

The analysis of spatial furniture with Finite element method (FEM) provides answers to many engineering problems. One of the fields which is not wholly solved is analysis of glued joints. In order to analyze joints by FEM it is necessary to have access to data on size and type of deformation which occurs as a result of overlap type of fit as well as data on thickness of the glue layer in joint. This paper provides answers to the impact of fit on the distribution of glue in the gluing surface. Test were conducted on oval mortise and tenon joint. The thickness of the glue line was measured on 800 samples. Based on the results the overlap occurred in the majority of samples (over 80 %). Average value of the thickness of the joint zone impregnated by glue amounted to 0.07 mm.

KEYWORDS: Chairs, joints, type of fit, FEM.

INTRODUCTION

The analysis of published papers in the field of application of finite element method (FEM) for the construction of chair or spatial furniture in general, indicates that a small number of researchers were engaged in this field. Generally looking, those papers can be divided in two major categories: papers where authors deal only with optimization of chair elements without analysis of joints, and papers where joints were analyzed.

In the first group of papers (Gustafsson 1996, 1997, Smardzewski 1998, Smardzewski and Gawronski 2001, Kasal et al. 2006, Laemlaksakul 2008, Çolakoglu 2012) joints was considered as rigid. Stress that occurs in joints was mostly defined as an inner stress without further analysis of type of fit, shape of plug and hole, thickness of the glue layer in joint or other factors that affect the strength of joint.

In the second group of papers, joints were analyzed. In those papers (Smardzewski 1998, Smardzewski and Papuga 2004, Gawronski 2006, Prekrat and Smardzewski 2010) joints was modeled with the presence of the gap between plug and the hole, while the type of fit and the machining accuracy were not specified. Gap between plug and the hole was used to place layer of glue. Width of the gap was 0.1 mm. Young's module of elasticity, and Poisson's ratio, which represents the basic parameters for definition of material used for model construction was overtaken from other papers. In some papers the strength of glued joints was analysed with the reflection to the thickness of layer in the joint (Lavisci et al. 2001, Pizzo et al. 2003, Feligioni et al. (2003)). However, in the aforementioned papers samples were constructed in accordance with the EN 302-2 2013 making the overlapping joint where the fit has no impaction joint strength.

On the other hand, based on previous scientific papers (Potrebić 1970, Rűdiger 1995, Skakić and Janićijević 2000, Džinčić 2006, Skakić and Džinčić 2006) and knowledge from industry practice, glued carpentry joints are produced exclusively with overlap fit, which represents significant factor of the joint strength. Among other, all aforementioned searchers came with three very similar conclusions: Type of fit and machining accuracy of the oval mortise and tenon affect the strength of joints and hence the strength and durability of chairs; the highest strengths of joints could be expected in small overlap fit; for the oval mortise and tenon joint recommended dimension of the overlap area should be from 0.1 to 0.2 mm.

Based on the analysis of published papers stands the questions: Why it was used joint with the gap for analysis of chair by FEM, and why width of gap was 0.1 mm? Three answers shows up: There is no data about thickness of compressed wood impregnated with glue, which is consequence of overlap fit; there is no data for Young's module of elasticity, and Poissons ratio for this new layer; it was impossible to make model of joint wit overlap in available software packages.

In compliance with all of these issues, there is a doubt about whether the proposed solutions reflect the true state in the real model? This dilemma does not diminish the importance of these works. On the contrary, it only supports the complexity of the problem that exists during chair modelling.

Objective of this paper is not to answer on all of these questions, but together with the paper (Džinčić and Skakić 2012) presents a small step on the way to make numerical model of joint with overlap using FEM. The results of this and further analysis will be treated as a contribution to the algorithms of existing software packages that operates on the principle of FEM. This paper presents an attempt to define thickness of glue layer in oval mortise joint with the presence of overlap fit. Oval mortise joint has been chosen as dominant type of joint.

MATERIAL AND METHODS

The influence of type of fit on the distribution of glue in the gluing surface was tested within two groups of samples which were assembled by oval mortise and tenon joint. The only variable within these two groups was type of fit while machine accuracy, gluing surface, type of wood, wood moisture content, quality of the glue and gluing regimes were controlled and remained constant. Joints from group A was produced with overlap. Value of overlap corresponds to the recommendations from the industry practice. Joints whithin second group (group B) was produced with gap of 0.1 mm, which corresponds to value from papers where joints were analysed by FEM. Every group of samples consisted of 50 pieces. Overview of joint parameters is shown in Tab. 1.

Tab. 1: Overview of joint parameters.

Group	Type of joint	Nominal measures (mm)			Class of machine accuracy	Type of fitting by the thickness of plug	Type of fitting by the height of plug
		L	B	D			
A	mortise - tenon	24	40	10	TD 15	K/p	K/p
B	mortise - tenon	24	40	10	TD 15	K/m	K/r

The samples were done in beech wood with dimensions: Leg 32x32x250 mm, rail 50x20x250 mm. Joints were glued with PVA-c glue produced by the RAKOLL, type EXPRESS 35. In order to create experimental conditions as much as similar to the manufacturing, samples were cut by chance regardless on their position in the log. Before the joints were made but also after the conditioning, moisture content of samples was controlled and it amounted to 9±2 %. Also, accuracy of the machines for production of joints was examined and it was determined that both machines work in the class of accuracy TD15 (DIN 68101 2012). Dimensions of joints were controlled by digital callipers with accuracy of 0.01 mm in two measuring spots. The glue was applied manually, while the spread of the glue on surfaces was controlled. The amount of applied glue was controlled by gravimetric method and it was determined that it was 200 g.m^{-2}. Clamping of samples was carried out in the horizontal frame press. Glued joints were conditioned at the room temperature of 23±2°C and relative humidity of 50±5 % for 30 days. Two samples were obtained from every probe by cutting of the joints by its height, Fig. 1. In total, 200 samples were obtained. The thickness of the glue line was measured on each sample in four spots which in total makes 800 measurements for the entire testing.

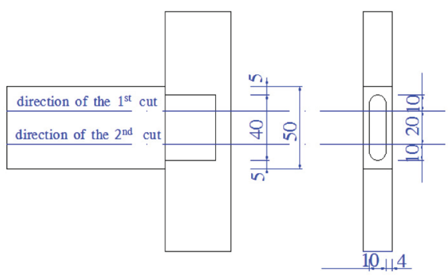

Fig. 1: Cutting of samples from corner joints – schematic view.

The thickness of the glue in the glued joint was determined by metallographic microscope equipped with Carl Zeiss - Jena camera. Magnification of the microscope ranged from 95 to 225 times. Thickness of the glue line was observed along the joint and photographed at 4 places.

RESULTS AND DISCUSSION

Results of this research are presented in the Fig. 2. The values shown in the graph are the means of measured thickness of the glue layer.

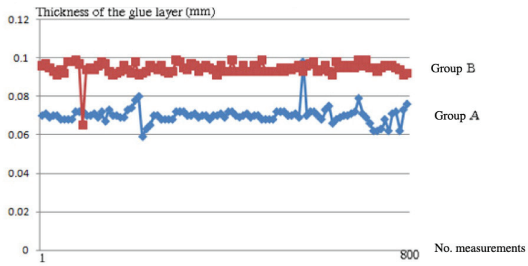

Fig. 2: Thickness of the glue layer – measuring results.

Based on the results of this research the following can be observed:

The overlap occurred in the majority of samples from the group A (over 80 %). Average value of the thickness of the joint zone impregnated by glue amounted to 0.07 mm, Fig. 2. Fig. 3 shows the usual appearance of the gluing surface of samples from the group A. On Fig. 3 glue line is not visible, only the compressed wood. On Fig. 4, which represents average appearance of glue line in samples B, glue is visible and it is placed in the gap between plug and the hole. As the tolerances fits to the normal distribution of measures along the field of tolerance, it can be concluded that the majority of samples shall distribute around the centre of the field of tolerance. Taking into consideration values of means for the field of tolerance of the hole and the plug, value of average overlap is 0.098 mm. Comparison between measured dimension of overlapping zone impregnated by glue and calculated value of the most frequent overlap shows that there is a deviation in experimental and calculated values (0.18 mm).

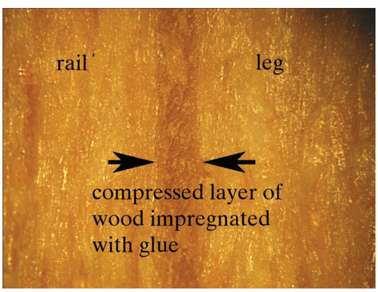

Fig. 3: Photo record of the average sample from the group A.

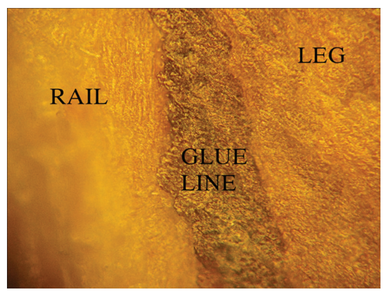

Fig. 4: Photo record of the average sample from the group B.

The analysis of values of samples from the group B shows that in the majority of samples (over 70 %) a gap occurred. The average thickness of the glue layer in the gap amounted to 0.095 mm. For all samples with the gap, glued line was not interrupted along entire length of joint. Comparison between average measured value of the thickness of the glued joint and calculated value of the most frequent gap that amounts to 0.09 mm shows that there is a small deviation in experimental and calculated values (only 0.005 mm).

As can be seen from above in joint with overlap fit there is no presence of pure glue. Instead of that, a new layer is detected. Deformation of joints caused by overlap with the presence of glue creates a new layer in joint. The new layer can be described as a compressed layer of wood impregnated with glue. Deformation of joint with the presence of glue probably leads to the change of Young's module of elasticity that represents the basic parameter for definition of material used for model construction. In order to analyse joints by FEM it is necessary to have data on size and type of deformation that occurs because of overlap as well as data on thickness of the glue layer in joint. As all carpentry joints are produced with the application of glue and adequate fitting, which is mostly overlap, there is a lack of information relating to the thickness of glue layer in joint. Based on the previous research and industrial practice it is recommended that the glued carpenter joints should be carried out with overlap fitting K/p (DIN 68101 2012). Data on the thickness of glue layer from aforementioned and similar papers, where glue was placed in gap of 0.1 mm, cannot be used for modelling joint by FEM. Complete modelling of joints, by some of the software packages that operate on the principle of FEM necessitates definition of the thickness of glue layer located in between plug and the hole. The analysis of publications in the field of application of FEM for the furniture construction and in the field of wood properties shows that this issue was not sufficiently researched nor the methodology for obtaining necessary data has been set. In order to model joint with overlap fit it is necessary to determine the values of Young's modulus of elasticity as well as Poisons coefficients for this impregnated – compressed layer of joint.

CONCLUSIONS

The performed investigation revealed that type of fit has influence on thickness of glue line. The pressure on tenon and mortise caused by type of fit changes thickness of glue line. In the case of loose fit thickness of glue, line corresponds to the assumed thickness given by other authors. However, in industrial practice this type of joint with the gap is not usual. In joint with overlap glue line is thinner. This glue line presents compressed wood impregnated with glue. This new formed layer probably has different properties than initial materials, and presents object of further investigation.

REFERENCES

1. Çolakoglu, M.H., Apay, A.C., 2012: Finite element analysis of wooden chair strength in free drop. International Journal of the Physical Sciences 7(7): 1105-1114.
2. Džinčić, I., 2006: Factors affecting rigidity and durability of chairs. Master thesis, Belgrade University, Faculty of Forestry (in Serbian).
3. Džinčić, I., Skakić, D., 2012: Influence of type of fit on strength and deformation of oval tenon-mortise joint. Wood Research 57(3): 469-478.
4. Feligioni, L., Lavisci, P., Duchanois, G., De Ciechi, M., Spinelli, P., 2003: Influence of glue rheology and joint thickness on the strength of bonded-in rods. Holz als Roh- und Werkstoff 61(4): 281-287.
5. Gavronski, T., 2006: Rigidity-strength models and stress distribution in housed tenon joints subjected to torsion. Electronic Journal of Polish Agricultural Universities, 9(4):
6. Gustafsson, S.I, 1996: Finite element modelling versus reality for birch chairs. Holz als Roh- und Werkstoff 54(5): 355-359.
7. Gustafsson, S.I, 1997: Optimising ash wood chairs. Wood Science and Technology 31(4): 291-301.
8. Kasal, A., Birgul, R., Erdil, Y.Z., 2006: Determination of the strength performance of chair frames constructed of solid wood and wood composites. Forest Product Journal 56(7-8): 55-60.

9. Laemlaksakul, V., 2008: Inovative design of laminated bamboo furniture using finite element method. International Journal of Mathematics and Computers in Simulation 4(3): 274-284.
10. Lavisci, P., Berti, S., Pizzo, B., Triboulot, P., Zanuttini, R., 2001: A delamination test for structural wood adhesives used in thick joints. Holz als Roh- und Werkstoff 59(1-2): 153-154.
11. Pizzo, B., Lavisci, P., Misani, C., Triboulot, P., 2003: The compatibility of structural adhesives with wood. Holz als Roh- und Werkstoff 61(4): 288-290.
12. Potrebić, M., 1970: Joint tolerance as effecting factor on strength of mortise joint. Master thesis. (Tolerancije spoja kao uticajni faktor na čvrstoću čepovne veze), magistarski rad, Univerzitet u Beogradu, Šumarski fakultet (in Serbian).
13. Prekrat, S., Smardzewski, J., 2010: Effect of glue line shape on strength of mortise and tenon joint. Drvna industrija 61(4): 223-228.
14. Rűdiger, A., Dusil, F., Feigl, R., Froelich, H.H., Funke, H., 1995: Grundlagen des Mőbel – und Innenausbau, DRW – Verlag, Stuttgart, 95 pp.
15. Skakić, D., Janićijević, S., 2000: Effect of type of joint, machining precision, and type of fit on the strength of the joints in chairs. (Uticaj vrste spoja, tačnosti obrade i vida naleganja na čvrstoću spojeva stolica) Drvarski glasnik 9(35-36): 21-25, Šumarski fakultet, Beograd (in Serbian).
16. Skakić, D., Džinčić, I., 2006: Influence of type of fit and on strength oval mortise tenon joint within chairs. (Uticaj vida naleganja na čvrstoću spoja čep-žljeb kod stolica). Prerada drveta 4(15-16): 12-15 (in Serbian), Beograd;
17. Smardzewski, J., 1998: Numerical analysis of furniture constructions. Wood Science and Technology 32(4): 273-286.
18. Smardzewski, J ., Gavronski, T., 2001: FEM algorithm for chair optimization. Electronic Journal of Polish Agricultural Universities, 4(2):
19. Smardzewski, J., Papuga, T., 2004 : Stress distribution in angle joints of skeleton furniture, Electronic Journal of Polish Agricultural Universities 7(1):

Igor Džinčić
University of Belgrade
Faculty of Forestry
Department for Wood Processing
Kneza Višeslava 1
11 030 Belgrade
Serbia
Corresponding author: igor.dzincic@sfb.bg.ac.rs

Dragan Živanić
University of Novi Sad
Faculty of Technical Sciences
Department for Mechanization and Design Engineering
Trg Dositeja Obradovića 6
21000 Novi Sad
Serbia