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Historical Application of Dovetail Corner Joints with Practical Example

Povijesni pregled primjene kutnih spojeva *lastin rep* s primjerom izrade spoja

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ABSTRACT • *This paper presents the most common traditional dovetail joints used in furniture making in past centuries, which are among the almost forgotten skills, practiced today by only a relatively small number of restoration workshops. The paper deals with the basic joints used in the restoration of furniture and traditional woodworking (houses, churches, temples, etc.) for the purpose of protecting rich cultural heritage. The history of furniture making is also the history of the art of making joints. In restoration, knowledge of these joints facilitates and accelerates the dating of furniture pieces to be restored. For this reason, the aim of this paper is to present an overview of the use of dovetail joints. The decorative effect of these joints and their constructive ingenuity certainly deserve more attention and research. A historical review of the development of traditional dovetail corner joints demonstrates the importance of the skill of crafting joints that stand the test of time and survive to this day. With the development of art, the joints became more and more decorative, but also of higher quality to withstand the various stresses that occur when furniture is used. Practical examples of making traditional dovetail corner joints are used to show how important it is to preserve the craftsmanship of these traditional joints from being forgotten, which is necessary when restoring furniture and other historical structural components made of wood such as ceilings, floors and altars.*

KEYWORDS: *traditional joint; dovetail corner joint technique; dovetail solid wood elements; restauration; furniture*

SAŽETAK • *U radu su prikazani najčešći tradicionalni spojevi nazvani lastin rep koji su se primjenjivali u izradi namještaja tijekom prošlih stoljeća, a čija je izrada danas gotovo zaboravljena vještina, koja se prakticira samo u relativno malom broju restauratorskih radionica. Prikazani su osnovni spojevi koji se primjenjuju pri restauraciji namještaja i tradicionalnoj obradi drva (kuće, crkve, hramovi itd.) radi zaštite bogate kulturne baštine. Povijest izrade namještaja ujedno je i povijest umijeća izrade drvenih spojeva. Poznavanje drvenih spojeva pri restauraciji olakšava i ubrzava datiranje namještaja koji se restaurira. Stoga je cilj ovog rada prikazati povijesni pregled primjene spojeva lastin rep. Dekorativni učinak tih spojeva i njihova konstruktivna domišljatost svakako zaslužuju veću pozornost i detaljnije istraživanje. Povijesni pregled razvoja tradicionalnih kutnih spojeva tipa lastin rep pokazuje važnost vještine izrade spojeva koji odolijevaju vremenu i primjenjuju se do danas. S razvojem umjetnosti spojevi su postajali sve dekorativniji, ali i sve kvalitetniji kako bi izdržali različita naprezanja što su nastajala tijekom uporabe namještaja. Praktični primjeri izrade tradicionalnih kutnih spojeva tipa lastin rep dat će doprinos*

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očuvanju umijeća izrade tih spojeva od zaborava, što je iznimno važno za restauraciju namještaja i drugih povijesnih strukturalnih elemenata izrađenih od drva poput stropova, podova i oltara.

KLJUČNE RIJEČI: *tradicionalni spoj; tehnika kutnog spoja lastin rep; elementi od punog drva lastin rep; restauracija; namještaj*

1 INTRODUCTION
1. UVOD

Joinery, the basis of woodworking, is a sophisticated blend of art and engineering (FPL 2010); strong joints will contribute to its longevity, while the design and craftsmanship enhance its beauty (Rogowski, 2002).

By observing wooden objects created in different historical periods, Fairham (2010) has analysed the handmade joints used to connect wooden elements over the centuries, which allowed for a firm joining of wood without the need for metal nails, particularly in handmade furniture and restoration.

There are many interesting joints that master carpenters have made with their acquired skills. This paper will provide an overview of the dovetail joint, which has clearly fascinated woodworking craftsmen throughout the centuries and continues to do so today. From simple to more complex versions, the dovetail joint has both, its functional simplicity and its explicit decorativeness. Of great significance is the fact that this joint bears witness to the history of the first great civilisations; it could even be said that it is "encapsulated in the history of mankind" with its tails and pins. The development of this simple but sophisticated combination and its variations is truly fascinating and goes far back into the history of crafting wooden objects.

In furniture making, it is necessary to create a structural system that justifies the durability and contributes to the aesthetics of the object itself (Hoadley, 2000). Joints, as a traditional segment of historical furniture, provide historians, conservators, restorers, curators and other related professions with information about the furniture itself, which is the subject of their interest.

Although there is a wide variety of joints, it is usually the dovetail that is of primary importance in furniture making. It is one of the most durable joints, whether it is a through dovetail joint, a full-blind joint or another type, which often reflects the quality of the workmanship and the mastery of the joints.

The dovetail joint got its name because of its resemblance to the shape of a bird's tail. This joint, which takes its name from the shape of the outstretched dovetail, has an unusual strength and rigidity that enables it to withstand repetitive strain in different directions (Bajalo, 1957; Coppola, 1993). A dovetail joint is extremely strong and is used to join two pieces of wood, usually the fronts and sides of drawers or the corners of chests (De Cristoforo, 1992).

In this paper, the importance and craftsmanship of handmade joints in woodworking will be explored, with a particular focus on the dovetail joint, which is a symbol of quality in traditional two-piece joinery. Additionally, as a practical supplement to literature review, the handmade creation of dovetail joints will be demonstrated, as well as bonding techniques including box joint, mitered-through dovetail, half-blind mitered dovetail and half-blind dovetail.

The aim of the paper is to highlight the importance of these joints today in the production of solid wood objects, especially in restoration, where the aesthetic and artistic component is very important in addition to functionality, and the craftsman's skill is required in the production process. Understanding the evolution of the described compounds will help readers appreciate how much woodworking technology and construction methods have advanced in the production of objects of artistic and historical value.

2 FROM CRAFT TO SYMBOLISM: LEGACY OF TRADITIONAL WOODEN JOINTS
2. OD OBRTNIŠTVA DO SIMBOLIZMA: KULTURNO NASLJEĐE TRADICIONALNIH SPOJEVA ZA DRVO

Through comprehensive literature research, the historical, structural and aesthetic value of traditional wooden joints will be explained, particularly in furniture making, their role in maintaining durability and beauty and their symbolic association with human skill and history.

In this article, the literature was selected according to the criteria of the basic principles of conservation and restoration of wooden objects. The experience of conservators and European institutes, that train students in conservation and restoration all over the world, has been used. The literature in this paper is mostly from older publications, which is entirely understandable given the historical nature of the subject. Recent publications are either reprints or reiterate established information about wood joints, with a particular focus on the dovetail joint.

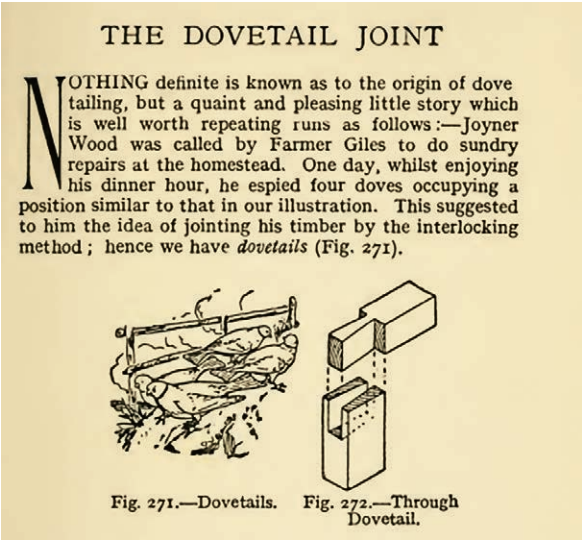
Kirby (2001) describes wood joined so that it cannot be split lengthwise. Most joints require some form of mechanical reinforcement to withstand the

force exerted on the object (Morić, 1995). Therefore, even though a properly glued joint is stronger than the wood fibres themselves, the adhesive will hardly withstand the forces acting on the joint when the furniture is in use. In addition to this property that provides strength, it is also very decorative (Rogowski, 2002). Whether crafted from a special, expensive wood, or a less expensive one, this joint is extremely attractive due to the contrast created by the different orientation of wood fibres (Banister, 1896). The construction of an object consisting entirely of wooden elements and wooden connecting elements certainly has a striking visual appeal (Granić, 1964). The characteristics of traditional joints are aesthetics, durability, and strength (Bierling, 1989; Pieresca,1992)

The small, subtle imperfections of the wood and the patina that inevitably comes with age inspire the observer to reflect and meditate on time, transience and the inherent imperfection of life. On the other hand, joints speak of perfection, the desire for enhanced performance, the precision of the cut and the final stroke of the chisel. An object crafted or built without other aids lasts longer because it harmonises with nature. The use of other materials to fix the wood disrupts the natural synergy.

2.1 A brief historical overview of development of dovetail corner joints
2.1. Kratki povijesni pregled i razvoj spoja *lastin rep*

One of the first joints that is often seen in old photos of antique furniture is a plain butt joint reinforced with a dovetail insert. (Figure 1). Edwards (2012) states that most high-quality antique furniture had a dovetail joint in its construction, which was so effective that it was used for centuries and continues to be used today in the manufacture of unique pieces, as well as in the restoration of furniture. For thousands of years, this joint has been made by the hands of master carpenters who used small precision saws and hand-forged chisels to finish the joints. Tails on one side and pins on the other, were precisely measured and manufactured to fit perfectly into a joint. Once the joint is completed, the individual pieces of wood become a single body of beauty and strength that can endure for centuries (Forest Products Laboratory, 2010).


THE DOVETAIL JOINT

NOTHING definite is known as to the origin of dove tailing, but a quaint and pleasing little story which is well worth repeating runs as follows:—Joyner Wood was called by Farmer Giles to do sundry repairs at the homestead. One day, whilst enjoying his dinner hour, he espied four doves occupying a position similar to that in our illustration. This suggested to him the idea of jointing his timber by the interlocking method; hence we have *dovetails* (Fig. 271).

Fig. 271.—Dovetails. Fig. 272.—Through Dovetail.

Figure 1 Image showing tails of four doves (left) from which a wooden joint (right) was created (Fairham, 1910)
Slika 1. Prikaz repova četiriju golubica (lijevo) na temelju kojih je kreiran drveni spoj (desno) (Fairham, 1910.)

Carpentry is the craft of joining wood, and in the context of structural connections, this term "traditionally" refers to wood-wood connections that are linked together by geometries that can provide the interlocking and friction necessary to transfer loads between elements while maintaining rigidity. Heritage structures with wood-wood connections can be found worldwide and date back hundreds or thousands of years depending on the locality (van Nimwegen and Latteur, 2023).

Many traditional techniques are millennia old, like Tibetan building techniques that date back 4500 years, and centuries-old timber structures like the Potala Palace and Jokhang Temple that still stand today (Guo *et al*., 2021). Structures with Dou-gong brackets, a common joint dating back as far as 770 BC, can still be found throughout heritage timber buildings in China, Korea, and Japan (Arlet, 2021). Egyptian archaeological sites have been known to exhume millennia old woodworking tools like hand saws, chisels, and mallets alongside artworks depicting carpenters using these tools (Lucas, 1934). This method can already be recognised in the Egyptian era in the furniture in which mummies were buried, in the pyramids and in the furniture built for the Chinese emperors (Janson, 1997). The dovetail dates back to the time of Ancient Egypt (1st Dynasty), 3000 BC at the latest, as it was found on various pieces of furniture, coffins and ivory from this period (Nicola *et al*., 2008). The earliest examples of this joint can be traced back to furniture that was kept together with mummies in ancient Egypt, as well as in the tombs of Chinese emperors and in Indian temples (Banister, 1896).

In his Ten Books of Architecture (25 BC), the Roman architect Vitruvius reports on methods of roof beam construction, including the use of "dovetail dowels". It is obvious that the compound was also used in construction, which can be seen in Roman buildings, where it appears in the manufacture of various pieces of furniture as well as in building structures. Vitruvius (1st century BC) mentions the use of a securicla (hatchet), i.e. a dovetail, in his discussions on the construction and methods of assembling roof beams. Although the observation of the transition from the Roman era to

Figure 2 Dovetail joints shown on the chest in the painting The Death of the Virgin, Dürer, 1506. (Reprinted from Hutchison (1990) with permission of Princeton University Press)
Slika 2. Spoj *lastin rep* prikazan na škrinji s Dürerove slike *The Death of the Virgin*, 1506. (preuzeto iz: Hutchison, 1990., uz suglasnost Princeton University Pressa)

the Middle Ages is very delicate and complex, it is clear that different variants of the dovetail continued to appear during this period (Charlish, 1976).

Early types of dovetail joints were quite large, even unwieldy, often additionally fastened with nails due to the tools that existed at the time. As the fineness of the tools changed, so did the joints become finer and neater (Welsh, 2011).

There is some evidence of dovetail chests in England from early times. A monk who was present when the tomb of St. Cuthbert (who died in 687 but was reburied several times) was opened in 1104 noted that one of the chests containing the mortal remains was made of jagged planks joined in different directions (Eames, 1977). Contemporary European art also provides us with visual representations of the use of the dovetail (Pischel, 1975).

The paintings by Dürer (Hutchison, 1990) along with a chair and a chest from 1506 (Danube School, 1522, Figure 2), show the common application of this joint in wooden furniture and other everyday items. It can be concluded, from the literature, that the development of this joint was a process of improving structural solutions over the centuries.

A development in the production of chests and small decorative caskets can be recognised in Italy in the 14th century (Figure 3), although the joints are often concealed by external decorations.

Figure 3 Dovetail corner joints on the chest from 14th century (https://tinyurl.com/297vu8of)
Slika 3. Spoj *lastin rep* na bočnim stranama škrinje iz 14. stoljeća (https://tinyurl.com/297vu8of)

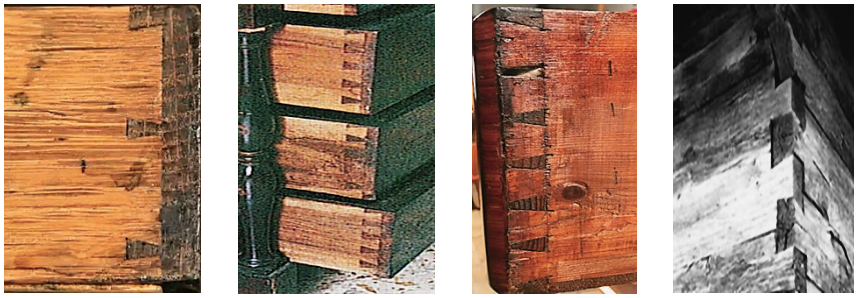
The joint mentioned was already used in antiquity, but it was not widely used until the 16th century, when the art of furniture making emerged as a distinct craft, separate from carpentry or woodworking. Originally this joint was made by hand, cut with a small saw and a chisel and glued with animal glue (Kumar, 2021).

English cabinetmakers began using dovetail joints on walnut furniture in the mid-17th century and continued to do so until the end of the 19th century when they were machine-made, particularly in the Edwardian period (Roe, 1902).

The secretary cabinet shown in Figure 3a, dating from around 1780, was made by a good countryside cabinetmaker. The dovetail on the side of the drawer was executed in the same way as the joint of the top and side boards (Melchert, 2003).

Dubarry de Lassale (2022) describes the evolution of dovetail crafting during the Empire and Restoration periods, spanning from 1804 to 1830, when the number of dovetail lines on commodes increased to seven (Figure 4).

This joint was most prominent and widely used in the making of drawers during the 19th century (Oats, 2021). It was revolutionary in every respect, resulting in numerous changes, which in this case required an increased need for the manufacture of furniture, especially furniture with drawers (Rivers, 2003). It was precisely for this reason that numerous patents were created, i.e. mechanical machines that could address this challenge. These various patents found the most fertile ground on the new continent, where between 1833 and 1900 numerous inventors registered 106 inventions of dovetailing machines (Reynolds, 1873). Over time, they evolved to become more refined and smaller with an increased number of pins, and their evolution reached its peak in the 19th century. There were no fixed rules for craftsmanship, it depended mainly on the craftsmen, their skills and the type of workshop they belonged to. In the larger workshops, there were masters who specialised only in the production of tenons (Arnston, 1965). This need gave rise to the art of making joints. In terms of furniture, it is necessary to establish a structural sys-



a) b) c) d)

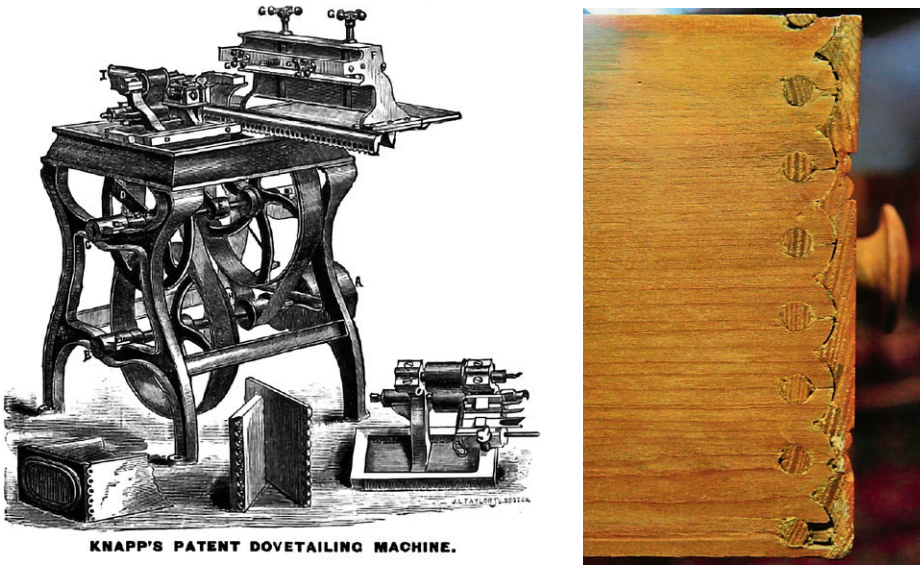
Figure 4 Display of dovetail joint in different countries: a) joint between the back and side panel of a chest, England, 1780 (https://tinyurl.com/2d72mlj8); b) drawers of a chest, Italy, 1825 (https://tinyurl.com/2636bz97); c) side panel of a chest, France, 1780 (https://tinyurl.com/2xmv9py4); d) wall joint in a wooden house, Croatia, 1902 (Živković, 2013)
Slika 4. Prikaz spoja *lastin rep* iz različitih država: a) spoj leđne i bočne strane škrinje, Engleska, 1780. (https://tinyurl.com/2d72mlj8), b) ladice škrinje, Italija, 1825. (https://tinyurl.com/2636bz97), c) bočna strana škrinje, Francuska, 1780. (https://tinyurl.com/2xmv9py4), d) spoj zidova na drvenoj kući, Hrvatska, 1902. (Živković, 2013.)

tem that justifies the durability and enhances the aesthetics of the piece.

As it evolved over the past 150 years, this joint has become an important factor in determining the age of an object. The dovetail joint model reveals a lot about the furniture and the period in which it was made. The craftsman's dexterity and skill are evident and reveal whether an object was made by hand or by machine. Until 1870, handmade joints were common all over the world. The date of manufacture of antique furniture can be estimated by examining the dovetail joint. If the joint was cut by hand, that indicates that it is a pre-1880 piece, and a more primitive cut usually means that a piece is from an earlier period (Mercer, 1929).

In the 1870s, inventors in America developed the first commercial machine for industrial production of furniture, which did not gain much popularity outside America and Canada. The so-called round style dovetail was produced, which is commonly found in furniture from the late Victorian period (Aronson, 1965) (Figure 5a).

The development of technologies that enabled faster manufacturing and mass production in this area followed in the 1890s, also in America. This marked the beginning of mass production of furniture for the rapidly growing upper middle class (Arnston, 1965). Machine-made joints are just as durable and long-lasting as those made by hand, but every cut is exactly the same, with no deviation, which is not the case with hand-made joints. That became the standard in furniture production in America from 1890 - until today. If you have an antique piece of furniture that features drawers with a curious-looking half-circle joint, you can be almost certain that it was made in a North American factory between 1871 and 1900. While it came to be known as the Knapp Joint, the joint is also variously



a) b)

Figure 5 a) Dovetailing machine (American Artisan, 1871), b) example Knapp dovetail (https://tinyurl.com/2c96woqf)
Slika 5. a) Stroj za izradu zubaca (American Artisan, 1871.), b) primjer spoja izrađenog Knappovim strojem (https://tinyurl.com/2c96woqf)

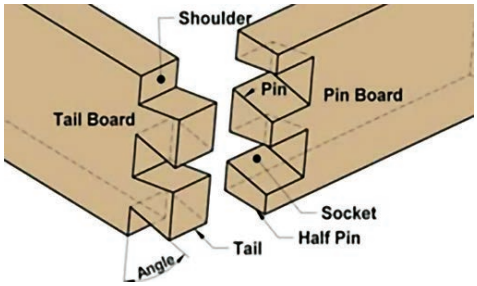


Figure 6 Mitered-through joint with marked details (https://tinyurl.com/23rcy6wb)
Slika 6. Spoj s otvorenim zupcima i označenim detaljima (https://tinyurl.com/23rcy6wb)

Figure 7 Robust miter joint (https://tinyurl.com/22ebx3l9)
Slika 7. Robusni spoj *lastin rep* (https://tinyurl.com/22ebx3l9)

described by its appearance: the pin and cove, scallop and dowel, scallop and peg, pin and scallop, and half-moon (Figure 5b)

Why the (rather brief) departure from dovetails? By the second half of the 19th century, most furniture in America was made by machines in industrialised factories—with the exception of fine drawers. Though people were patenting machines that could produce dovetails (106 patents for the like applied for between 1833 and 1900!), no one had yet developed an appealing way to cut more than one uniform pin and tail at a time (See the Burley & Putman Dovetailing machine, patent nos. 12,122 and 26,647).

From simple carpentry to sophisticated decorative joints, from basic construction techniques to the highest standards in furniture making - dovetail joints represent the history of furniture making, wood construction and production. This open miter joint was crafted in wood construction/carpentry, using a "dovetail" shape that is projected onto wood designed to fit wood of equal size. (Figures 6, 7).

There is a great deal of literature attesting to the importance of handmade joints, especially dovetails. The joint is still interesting today because of its aesthetic and mechanical properties, and not only in restoration (Bullar, 2013; Bridgewater *et al*., 2014; Fleming 2020).

The master carpenters were not overly satisfied with this type of joint, as the adhesive properties, i.e. the adhesion of the veneer to the joint, were not adequate when the veneer was applied. Other types of joints such as "half-blind mitered joint" and "secret mitered joint" have arisen from this need (Jones and Lutes, 1993).

2.2 Crafting traditional joints: tails and pins (teeth)
2.2. Izrada tradicionalnih spojeva: repovi i igle (zupci)

2.2.1 Materials for making dovetail joints
2.2.1. Materijali za izradu spojeva *lastinim repom*

Dovetail joints are very common in carpentry due to their strength and aesthetic value. They were mostly used to join pieces of wood together at an angle to make solid wood furniture (Jackson *et al*., 1996). The wood used for these joints must be sufficiently strong, stable and resistant to bending. Research by Hoadley (2013) has shown which types of wood are traditionally used to make dovetail joints.

Oak is the best known and most valued timber material for the manufacture of dovetail joints due to its exceptional strength, stability and durability.

Ash is also very popular for the production of dovetail joints due to its strength and flexibility, slightly softer than oak used in furniture construction and very impact resistant.

Walnut is a wood that is used for the production of high-quality furniture. Due to its fine texture and beautiful colours, walnut wood is highly valued in joinery, especially for making dovetail joints in furniture of high aesthetic and artistic value in restoration.

Pine is a softwood that is used for dovetail joints when the high strength of hardwood is not required.

Yew is a very resistant and stable wood used for precise joints, especially in the manufacture of antique furniture. It is wear resistant and has a beautiful texture that lends itself to fine detailing in dovetail joints.

Larch, the hardest wood species among conifers with a density of 590 kg/m³ (when dry), medium strength, which enables the cutting of precise joints. Resistant to moisture and rot, aesthetically and decoratively interesting due to the fineness of the rings and the colour. When choosing the type of wood for dovetail joints, the key criteria are strength, resistance to cracking, and stability to retain shape over time. Dovetail joints provide high joint strength, support loads, and require great precision in manufacturing, which is crucial for the longevity and stability of furniture.

In this paper, handmade creation of dovetail joints will be demonstrated. For that purpose, larch wood was used, which was sawn from larger logs with bark to the appropriate dimensions, after calculating the size and number of teeth.

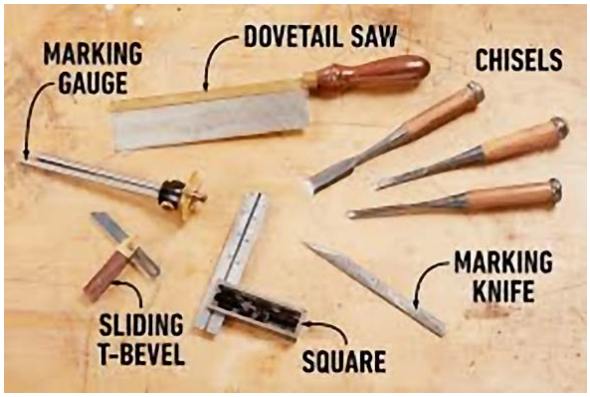


Figure 8 Dovetail tool (https://tinyurl.com/256zlqyf)
Slika 8. Alat za izradu spoja *lastin rep* (https://tinyurl.com/256zlqyf)

Figure 9 Captain Vlaho Podic's sea chest from 1871, dovetail corner joints
Slika 9. Pomorska škrinja kapetana Vlaha Podića iz 1871, kutni spoj *lastinim repom*

2.2.2 Hand tools for making dovetail joints
2.2.2. Ručni alati za izradu spoja *lastin rep*

After selecting the type of wood, it is necessary to choose the appropriate tools for manually making joints (Moxon, 2013). Specific hand tools are recommended for making dovetail joints, as they allow for precise shaping and the creation of a strong joint. The main tools (Glennon, 2018) used for this type of joint are: hand saws for precise cutting of wood according to the required dimensions of the joint; fine saws for precise cutting along thin lines, ensuring that the joints are accurate; a flat chisel for removing excess material and precisely shaping the joints; a specialised chisel with a thin blade for shaping the interior of the joint and detailed wood sculpting, especially in narrow and precise joint spaces; a wooden or rubber mallet for striking the chisel to shape the details of the joint; a marking gauge for marking the depth of the cut; a marking knife for exact marking of the cut line; clamps for fixing wooden pieces; a combination square and dovetail marker; scrapers for smoothing and levelling the joint surfaces; and files and fine planers for fine finishing of the joint, removing sharp edges, or precisely adjusting the joint dimensions (Figure 8).

2.2.3 Making and use of dovetail joints today
2.2.3. Izrada i upotreba spojeva napravljenih *lastinim repom* danas

The production and use of dovetail joints still plays an important role in modern woodworking, especially in the production of high-quality furniture, individual pieces and in the restoration of antiques. Today, CNC (computer numerically controlled) machines are often used to produce precise joints that speed up production and ensure high accuracy (https://tinyurl.com/2beapzom)

However, many craftsmen still prefer to produce dovetail joints by hand due to their aesthetic appeal and symbolic value. Dovetail joints are still widely used in furniture making, especially for the construction of drawers and boxes, as they offer exceptional stability and durability. These joints help to distribute weight evenly and prevent damage, which is crucial for the long-term performance of furniture (Conover, 2009.)

The use of these joints imparts a traditional aesthetic to furniture, enhancing its overall visual appeal. In some cases, the joints are intentionally left exposed as a decorative feature.

Reviewing the literature, it is surprising how frequently the dovetail joint is depicted and described. It can be concluded that this joint was not used solely for its aesthetic appeal, as noted in the literature, but also for its durability, stability, and functionality. Restored objects dating from the 18th and 19th centuries are predominantly inlaid and polished, with some even featuring polychrome surfaces, yet all share the structural characteristic of dovetail joints. It is well understood how challenging surfaces with inlays and intricate patterns can be. Even after so many years, these objects remain stable and retain their significant artistic value, thanks to the dovetail connection provided the necessary stability and strength to the entire structure.

The marinet chest from 1871 has a painting on the entire surface, which has remained sufficiently stable because the dovetail joint connecting front and side panels (Figure 9, orange markings on the right-hand side of the picture) not only enhances the aesthetic impression of the chest but also ensures the construction of the period and the painting on the surface. This shows that the dovetail joint is durable, reliable, strong and stable for objects of historical value. Therefore, the preservation of these joints is unquestionable, even if they are not attached to the fronts but to the inside, as the example in Figure 10. The drawers of a chest of drawers from the 19th century, which is completely veneered and polished, retain the stability of the entire body and thus the aesthetically refined surface. The

a)

b)

Figure 10 Drawers of a chest: a) drawer front, b) drawer back
Slika 10. Ladica škrinje: a) prednja strana b) stražnja strana

dovetail joint is part of the historical heritage and there is a need to demonstrate its importance as the most important constructive element of a wooden object cultural heritage.

There would be movement in the supporting elements, leading to instability in the painted and inlaid surfaces of wooden objects, as seen in paintings from the 19th century. The importance of the dovetail joint lies not only in its historical significance but, more importantly, in its structural function.

Today, dovetail joints are frequently employed in the restoration of antiques, where preserving traditional techniques is considered crucial. They are also commonly used in the luxury market, where superior craftsmanship and long-lasting durability are essential.

3 ART OF DOVETAIL JOINTS: A PRACTICAL EXPLORATION OF TRADITIONAL HANDCRAFTING
3. UMJETNOST SPOJEVA *LASTINIM REPOM*: PRAKTIČNO ISTRAŽIVANJE TRADICIONALNE RUČNE IZRADE

Based on the knowledge of the historical development, a practical example of the production of the dovetail joints has been presented. The importance of preserving the tradition of handcrafting techniques is demonstrated from the selection of the type of wood used to make the joints and the tools used to make the joints by hand, to the determination of the pattern dimensions, number of patterns, determination of the size, arrangement and spacing of the teeth of dovetail joint. The wood was sourced from the remnants of previously used larch boards, measuring 37 cm × 45 cm × 5 cm. These were used to create a handmade box joint, beveled foundation dovetail, semi-blind beveled dovetail, full blind dovetail, and dovetail joint. The bark was removed from the wood, and the resulting samples were sawed in half in both directions. The pieces were then glued together to a dimension of 16 cm × 16 cm. This procedure was carried out with 12 samples. The materials used for crafting the dovetail joints included simple hand tools: a saw, chisel, hammer, and measuring and drawing tools.

3.1 Methodology for making a dovetail joint
3.1. Metodologija izrade spoja *lastin rep*

Determining the size, arrangement, and spacing of the teeth in a dovetail joint (the so-called "tooth joint") requires precise planning to ensure that the joint is strong, aesthetically pleasing, and functional. Based on examples from the literature, the following is an overview of the process for making a dovetail corner joint, accompanied by illustrations: divide the end of one piece into six equal divisions. Use a doventail template and pencil to mark on the tails shade the areas to be removed. Mark the lines across the top and down the other side. Place the wood in the vice at a slight angle, so that sawing is vertical (straight down). Take care to saw on the waste wood side of the lines (which will be removed after making each „tooth") using a doventail saw. Use a coping saw to remove the waste wood, cutting just above the depth line between each tail. The blade of the coping saw may need turning sideways (Figure 11).

Analysing the literature for standard guidelines for tooth size, it was determined that the height of the tooth should be between 1/3 and 1/2 the thickness of the wood, the width of the tooth should be approximately 1/2 to 2/3 the width of the wood, and the number of teeth in a dovetail joint will depend on: the dimension of the joint (the number of teeth increases with larger joint dimensions; smaller joints may have 4-6 teeth, while larger joints may have 8 or more), the function of the joint (depending on the load, the number of teeth will be greater to increase the strength of the joint; for lighter loads, fewer teeth may be needed), and aesthetics (in fine wooden objects, the number of teeth may be fewer, while in more massive structures such as boxes and drawers, it may be greater).

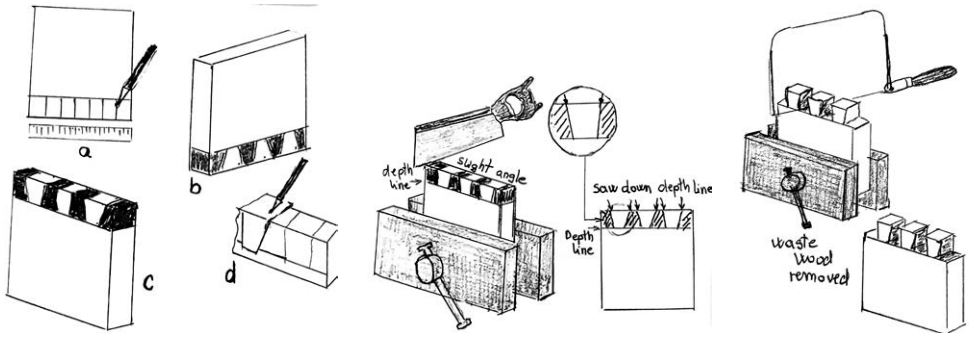


Figure 11 Making a dovetail join
Slika 11. Izrada spoja *lastin rep*

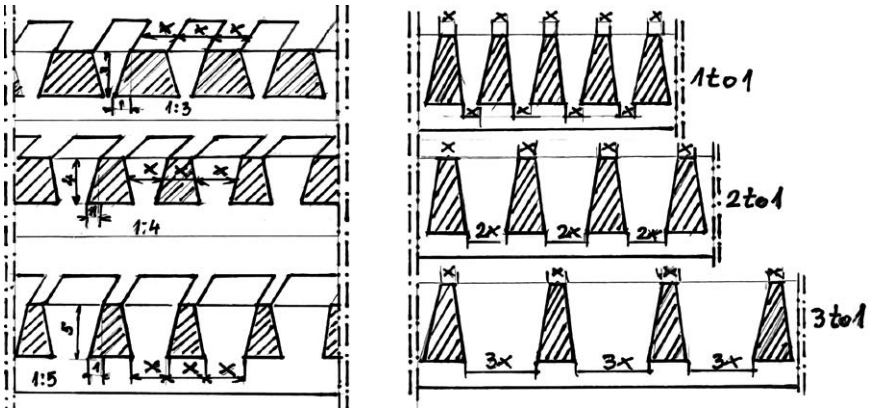


Figure 12 Different ratios in dovetail joint
Slika 12. Različiti omjeri u spoju *lastin rep*

The recommended distance between the teeth is 1.5 to 2 times the width of the tooth (for example, if the width of the tooth is 10 mm, the distance between the teeth should be about 15-20 mm).

The angle between the teeth in a dovetail joint is about 7° to 14° (a smaller angle means a tighter joint, making it more difficult to create; a larger angle makes it easier to make the joint, but reduces its strength).

Proper sizing, placement, and spacing of teeth in a dovetail joint are critical for creating durable, functional, and decorative joints. Although parameters can be adjusted depending on the specific application and desired strength, ensuring the proper balance between height, tooth width, and spacing will allow for optimal results. The practicality and visual appeal of the "dovetail" in tenon joints are determined by the angle of the cut. The proportions and angles tell us a lot about the master as well as the degree of sophistication of the construction (Figure 12). The earliest ratio of the joints was usually 1:1 (<45°). In the early 17th and 18th centuries, the ratio was 1:2 or 1:3, which shows a not very sophisticated but nevertheless practical technique (Jones and Lutes, 1993).

It is generally recognised that the 1:5 (11°) or 1:6 (9.5°) ratio is the strongest version of the joint and the one most commonly used. Any ratio exceeding this,

Figure 13 Through dovetail, 1:5 (https://tinyurl.com/26lyt3am)
Slika 13. Spoj otvorenim *lastinim repom*, 1:5 (https://tinyurl.com/26lyt3am)

Figure 14 Half-blind dovetail, 1:8 (https://tinyurl.com/28xv4f2w)
Slika 14. Spoj poluzatvorenim *lastinim repom*, 1:8 (https://tinyurl.com/28xv4f2w)

such as 1:7 or 1:8 (7°), as we can see on furniture designs from the end of the 18th century, represents an exaggeration both in terms of construction and functionality (Figure 13 and 14). All variants and types of joints are originally made by hand, chisel or saw, or a combination of these. Written markings are often visible as a guide for the craftsman when measuring and cutting, and small irregularities in the size and spacing of the cuts are common. The value of skill in crafting these joints is undeniable, so this paper will demonstrate the manual production of tenon-dovetail joints.

4 PRACTICAL EXAMPLES: HAND-MADE DOVETAIL CORNER JOINTS
4. PRAKTIČNI PRIMJERI: RUČNA IZRADA SPOJA *LASTIN REP*

Based on historical records research, this paper offers a brief account of the process of making tenons with traditional hand tools, such as saws and chisels, which requires unique skills of craftsmen.

The process of crafting tenons begins with the selection of high-quality wood that has a uniform texture and fibres. In addition to selecting the wood, it is also important to determine the size of the tails and pins by measuring and marking them accurately.

After measuring and marking (Figure 15 and 16), several cuts were made within the marked lines using a saw, ensuring that removing the marked parts with a chisel would not cause the fibbers to be pulled out or the wood to crack. The wood on which the teeth are made is additionally reinforced with two boards; black arrows indicate one on the back, at the height of the teeth, and the other along the bottom line, corresponding to the depth of the teeth (Figure 14a and 14b). The reason for the additional reinforcement is to provide resistance to the force of the chisel impact and prevent damage when making the teeth. After finishing one side halfway with the chisel, the board needs to be turned over, and the rest should be removed with the chisel, repeating the process. The reason for not chiselling all the way through on one side is that it could cause the wood to crack, and this method avoids that. The result is a clean and neat joint (Figure 14c).

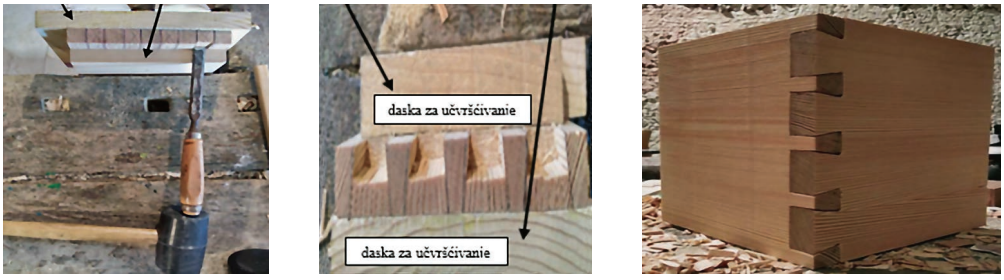
In this example of making semi-open oblique teeth, the height of the teeth is 1/3 shorter than the thickness of the wood, because the second part extends up to 2/3 the thickness of the wood (Figure 17). When making furniture, this joint is placed at the front side, (e.g., for a drawer).

Making a joint with hidden teeth is a process where the teeth cannot be seen from the outside. This joint is used in the production of finely polished furniture. When making this joint, 1/3 of the height of the wood is removed, but not the entire thickness - only 2/3 of it. Then, lines are drawn on the resulting face, along which oblique teeth are made. These teeth are cut at an angle of 45°, so that when they are subsequently joined with the other part, an angle of 90° is formed, and the joint itself remains hidden (Figure 18).

a) b)

Figure 15 Marking patterns for making dovetail corner joints: a) straight teeth of a dovetail joint, b) angled teeth of a dovetail joint

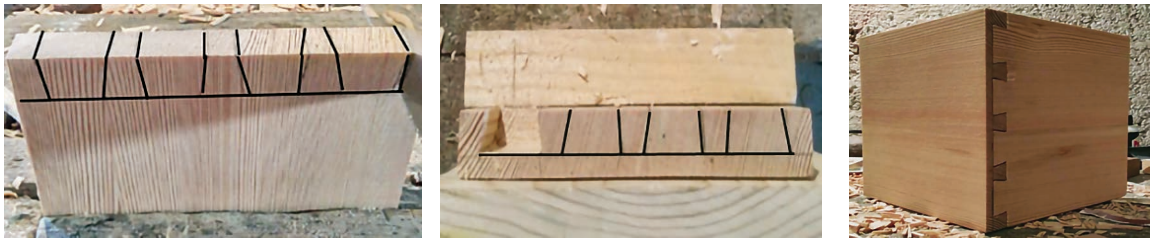
Slika 15. Oznake pri izradi kutnih spojeva *lastin rep*: a) ravni zupci spoja *lastin rep*, b) kosi zupci spoja *lastin rep*



a) b) c)

Figure 16 A mitered-through dovetail: a) marking out, black arrows indicate auxiliary panels used to secure the joint, b) hand crafting, c) final joint

Slika 16. Otvoreni spoj *lastin rep*: a) označivanje: crne strelice označuju pomoćne ploče koje služe za učvršćivanje spoja, b) ručna izrada, c) izrađeni spoj



a) b) c)

Figure 17 Crafting a semi-blind mitered dovetail: a) marking out, b) crafting, c) final joint
Slika 17. Izrada poluzatvorenog spoja *lastin rep*: a) označivanje, b) izrada, c) izrađeni spoj

a) b) c)

Figure 18 Crafting a full-blind dovetail: a) marking out, b) crafting c) final joint
Slika 18. Izrada zatvorenog spoja *lastin rep*: a) označivanje, b) izrada, c) izrađeni spoj

Dovetail as reinforcement is another useful application of this joint element. It is used to strengthen and secure a wooden joint on a flat surface that is reinforced with a dovetail insert that prevents the joined surface from coming loose. Reinforcement is used in the production of tabletops, larger altar surfaces with carved boards, floors and wall panelling. With a cut, the wood is sawed in half. A dovetail shape is carved into the resulting pieces (Figure 19), which will eventually be joined with a piece of wood in the shape of a dovetail.

The art of making the above-mentioned traditional joints, which can be traced back through history, is particularly interesting in workshops for the restoration of furniture and other historical wooden components (ceilings, floors, altars).

The results of handmade dovetail joints in a restoration workshop, based on the literature, show that they still have the same importance in the manufacture of solid wood furniture today, after centuries of use.

5 CONCLUSIONS
5. ZAKLJUČAK

Traditional joints in furniture making have evolved over the centuries with no major variations in production, except that they have become more precise and finer in execution. Drawings and calculations from the literature are used to show how the traditional joints are made using simple tools, saws and chisels. It is obvious that the joint has been used for centuries because of its properties: Strength and stability, durability, aesthetics, preservation of tradition and acquired skills. This paper emphasises the importance of preserving traditional methods and their application in today's world of cultural heritage preservation and presents an

a) b) c)

Figure 19 Crafting of a dovetail joint: a) elements, b) making a groove, c) final joint
Slika 19. Izrada spoja *lastin rep*: a) elementi, b) izrada utora, c) izrađeni spoj

example of the production of open, semi-open and concealed dovetails, focusing on the name of the joint corner dovetail. In the restoration of wooden objects, the dovetail joint is still the most common today, and knowledge of the development and skills involved in making the said joint is necessary for students studying conservation and restoration. It can be concluded that this joint was not used solely for its aesthetic appeal, as noted in the literature reviewed for this paper, but also for its durability, stability, and functionality. Over the last 30 years, there have been fewer and fewer students in woodworking schools. The skills that master carpenters had in the manual production of joints in solid wood are rarely passed on to students. It is therefore particularly important that traditional joints continue to be made by hand so that they can be used in the restoration of wooden objects in the future.

Today we admire master carpenters who were inspired by their own culture, historical influences and the beauty of nature and the materials that nature gave them, creating works of art with their own hands and simple tools. In addition to the external beauty, there is the skill and knowledge of the masters, who have passed on their furniture-making expertise from generation to generation and perfected the execution of dovetail joints. However, the harmony of the creation conceals the complexity of the joint itself. Nothing can replace the elaborate joining technique, neither in terms of aesthetics nor design, and especially not in terms of the quality of the workmanship. From today's perspective, one can only admire the ingenuity, virtuosity and patience of master craftsmen in the production of solid wood furniture.

Although dovetail joints offer undeniable advantages such as exceptional strength, durability and aesthetics, they are not without drawbacks. The production of dovetail joints requires a high level of precision and craftsmanship, making them very demanding and sometimes time-consuming. Furthermore, the process can be slow and requires a lot of patience due to the manual labour required, which can be a challenge in today's industrial production, which is focused on speed and efficiency. Furthermore, while the joint is extremely strong, it is sensitive to changes in humidity and temperature, which can lead to deformation if not done properly or if unsuitable materials are used. Despite these disadvantages, the dovetail joint is still a symbol of high quality in furniture construction and has its place in modern restoration practise, where it is still used in the restoration of historical wooden objects.

Examples shown in Figure 9 and 10 confirm all the listed properties of the dovetail joint with particular emphasis on the durability, hardness, elasticity and stability of wooden objects from the University wood restoration workshop.

From today's perspective, it can be concluded that joints such as the dovetail joint are still essential for the preservation of cultural heritage, but that it is important to balance them with innovation to ensure the longevity of these skills in a modern context.

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