Joinery Design for Joint Type I, L, T, X, and XYZ in Aluminum Pipe

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Abstract. Aluminum pipe is one of the most widely used materials for indoor and outdoor furniture because of its durable characteristics and low price. In general, furniture with aluminum pipe material is not detachable because the connection method is permanent, namely by the welding process. This design aims to design a multi-case joinery that can be used for connection types I, L, T, X, and XYZ, which can be unplugged and used for various types of furniture. The design method used is qualitative by conducting literature studies and observations on existing products as well as an exploratory method to find the basic form of the joinery and the aluminum pipe lock system to the joinery. This research aims to create a connection system for connection types I, L, T, X, and XYZ that can be unplugged and to provide a new alternative for connecting two or more aluminum pipe components. Based on the research results, the basic form of the joint system that can be used for joint types I, L, T, X, and XYZ is detachable and has a flexible shape for ¾ inch aluminum pipe material.

1 Introduction
Currently, furniture with aluminum pipe material is quite popular because of its long-lasting characteristics and not easy to corrode or rust. However, the type of furniture with aluminum pipe material that is common on the market is furniture that cannot be removed because the process of connecting each component is permanent using a welding technique or difficult to remove because it uses fittings and screws as the lock. Seeing from the permanent connection system that is difficult to remove, making furniture with aluminum pipe material requires a large enough area or space in the shipping process from the factory to the shop or from the shop to the buyer. This is due to the lack of alternatives or options to connect two or more aluminum pipe components.

A joint or connecting system means a system that can connect two things or components into one group. The joint system is a component that is commonly used and is quite common in furniture. The term joint system is widely used, especially in furniture with wood materials where the type of joint system can be removed and can be formed according to needs in terms of function and visuals because the joint system in wood is the wood itself. In contrast to aluminum pipe materials, the way to connect two or more aluminum pipe components is generally only by welding or using fittings.

In aluminum pipe furniture, various types of connections are quite often used, namely, type I, type L, type T, type X, and type XYZ. Each of them are:
- Type I connection is a type of connection that connects the first aluminum corner to the second aluminum corner so that it forms the letter “L”.
- Type L connection is a type of connection that connects the two aluminum pipes form 90° or perpendicular. This type of joint connects one edge of the aluminum to one of the center edges of the second aluminum forming a "T".
- Type X connection is a type of connection that connects two aluminum stacked on top of each other and crosses or a connection that connects two to four aluminum facing each other and produces the letter “X”.
- XYZ-type connection is a type of connection in which three pieces of aluminum are located on the X, Y, and Z axes respectively to form a 3-dimensional angle.

Based on this design background, the following problem formulation can be made:
1. Designing a joint system that can be used in cases of I, L, T, X, and XYZ connections on aluminum pipes.
2. Designing a joint system that can be removed and reinstalled on aluminum pipes.
3. Design a joint shape and locking system that can be used for connection types I, L, T, X, and XYZ.

The final purpose of this study are to generate detachable joint systems for connection types I, LT, X, and XYZ, and also to provide a new alternative for connecting two or more aluminum pipe components.

2 Research method
In this study, qualitative and exploratory methods were used to interpret the phenomena that occur in which
there are various existing methods [1]. The process used in the qualitative method in this design is a literacy study and a precedent study. A literature study is carried out by searching and collecting data through books, journal articles, and the Internet. The data collected to support this design is the search for data regarding the joint system. From the data obtained from the literacy study, a precedent study was then carried out by looking at and comparing joints for aluminum pipes that are already on the market. The purpose of this precedent study is to see whether the joint system to be designed is already on the market and to find out what kind of joint system is already on the market. The precedent study, shown in Table 1, takes 3 joint systems, namely Interclamp by Interclamp [2], 'Stick' Shelving System by Menu [3], and MoMo Modular Furniture by TACADI [4, 5].

<table>
<thead>
<tr>
<th>Joint System</th>
<th>Interclamp by Interclamp</th>
<th>'Stick' Shelving System by Menu</th>
<th>MoMo Modular Furniture by TACADI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detachable</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>It can be removed and reused</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>It can be removed and reused into new furniture</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Tool-free installation</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Can be used in more than 1 type of joint</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

From Table 1, the study which contains 3 combined systems on the market produces several points:
1. Most of the joint systems on the market can be removed.
2. Most of the joints can be reused with the conditions of the joints still fit for use.
3. Not all joints can be removed and reused as other furniture.
4. Most of the joint systems on the market require the help of tools such as a screwdriver to install them.
5. Not all joint systems can be used for more than one type of joint.

Judging from the points above, the joint system that will be designed has advantages in the joint function which can be used for more than one type of joint, namely for joint types I, L, T, X, and XYZ as well as in the joint function which can be removed and installed. After the precedent study process, an exploratory method is carried out by looking for what type of joint can be used or used for joint types I, L, T, X, and XYZ and proving whether the study carried out is feasible to become a joint system. This exploration process was carried out by making 3D modeling and by mock-up studies using plastic pipe material as a substitute for aluminum pipes, explained in the Table 2.

<table>
<thead>
<tr>
<th>Code</th>
<th>Study</th>
<th>Joint Types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>J01</td>
<td>![Image]</td>
<td>✓</td>
</tr>
<tr>
<td>J02</td>
<td>![Image]</td>
<td>✓</td>
</tr>
<tr>
<td>J03</td>
<td>![Image]</td>
<td>✓</td>
</tr>
<tr>
<td>J04</td>
<td>![Image]</td>
<td>X</td>
</tr>
<tr>
<td>J05</td>
<td>![Image]</td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 2 shows that 6 of 10 studies can be used for joint types I, L, T, X, and XYZ, and one of the 6 studies (J07) has more than one component. After carrying out a search study and proving the shape of the joint, a search and proving study was carried out for the aluminum pipe locking system for the designed joint. The study process was carried out by making 3D modelling and by mock-up studies and exploring more about the lockdown system that using pine wood materials, dowels, and glue in Table 3.

<table>
<thead>
<tr>
<th>Code</th>
<th>System</th>
<th>Study</th>
<th>Operating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Drat</td>
<td><img src="image1" alt="Image" /></td>
<td>Rotating aluminum pipe goes into the joinery components</td>
</tr>
<tr>
<td>S2</td>
<td>Ball System</td>
<td><img src="image2" alt="Image" /></td>
<td>Pressing the button so that the ball goes inside, and the aluminum pipe can enter the joinery components</td>
</tr>
<tr>
<td>S3</td>
<td>Glue</td>
<td><img src="image3" alt="Image" /></td>
<td>Aluminum pipe is glued</td>
</tr>
<tr>
<td>S4</td>
<td>Cross System</td>
<td><img src="image4" alt="Image" /></td>
<td>The aluminum pipe is inserted into the joint and then the cross is inserted into the joinery and pipe holes</td>
</tr>
</tbody>
</table>
Table 3 shows the results of the search and verification study of the lockdown system which resulted in 4 studies with different systems namely:

1. Thread the system by threading the aluminum pipe in the joint area where the aluminum pipe will be inserted.
2. The ball system with a hole in the aluminum pipe for the ball entry area from the joint and there is a button that can insert and remove the ball-shaped lock from the joint.
3. Gluing by applying glue to aluminum pipes and joints.
4. The cross system by perforating the aluminum pipe for the cross-entry area and there is a hole in the joint which has a function as the cross-entry area so that the aluminum pipe can be locked.

3 Result and discussion

After going through the stages of literature studies, precedent studies, and exploration which resulted in 10 joint form studies and 4 locking system studies, then an analysis of the advantages and disadvantages of each study was carried out to find out which studies could be used as the results of joinery designs for joint types I, L, T, X, and XYZ on aluminum pipes (Table 4).

Table 4. Analysis of search studies and evidence of joint forms.

<table>
<thead>
<tr>
<th>Code</th>
<th>Study</th>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
</table>
| J01  |       | - Can be used for type I and L joints.  
- Does not require additional tools to change the position of a straight joint to a 90° elbow.  
- Pipes can be stationary or static because there are supports that hold the pipes. | - Cannot be used for connection types T, X, and XYZ.  
- In the middle of the joint, there is a system to rotate the joint so that it can be used for the L joint.  
- There is a possibility that it will not be able to withstand the load in the long term because it can damage the rotary system in the middle of the joint. |
| J02  |       | - Can be used for type I, L, and T joints.  
- Pipes can be stationary or static because there are supports that hold the pipe for type I and L joints. | - Cannot be used for X and XYZ connection types.  
- For T-type joints, the pipe to be inserted only has support on the right and left so that it can still be swayed to the front and back (not static).  
- There is an empty and open side when the joint is 90° angled. |
| J03  |       | - Can be used for type I and L joints.  
- Does not require additional tools to change the position of a straight joint to a 90° elbow.  
- Pipes can be stationary or static because there are supports that hold the pipes. | - Cannot be used for type X connections.  
- For the use of the XYZ joint, the X and Z sides have different heights (not parallel).  
- There is a possibility that Joint XYZ cannot support the pipe optimally because the pipe support area is only half of it.  
- For T-type joints, the pipe to be inserted has only support at the side.  
- There is an empty and open side when the joint is 90° angled. |
| J04  |       | - Can be used for L and XYZ-type joints.  
- Has only one shape or does not need to drive components to be used in other types of joints.  
- The pipe can be stationary or static because there is a support that holds the pipe for the L joint. | - Cannot be used for connection type I, T and X.  
- There is an empty and open side when used for L-type joints.  
- For XYZ-type joints, the pipe to be inserted only has support on the right and rear so that the pipe cannot stand (not static). |
| J05  |       | - Has only one shape or does not need to drive components to be used in other types of joints.  
- All sides of the hole can be inserted into the pipe.  
- Can be used for type I, L, T, X, and XYZ joints.  
- Easy joint operation. | - The distance between the holes is too thin so it is easy to break.  
- One side of the hole cannot be inserted because the hole is too small. |
| J06  |       | - Has only one shape or does not need to drive components to be used in other types of joints.  
- All sides of the hole can be inserted into the pipe. | - Because it is in the shape of an elbow, when using joint type I there is one side that is not used and produces a disturbing visual. |
From Table 4 which shows the search analysis and form proof above, 1 study was selected out of 10 studies, namely research with code J08 for the following reasons.

1. Study J08 can be used for joint types I, L, T, X, and XYZ the same as studies J05, J06, J07, J09, and J10.
2. Study J08 has a support area that can hold the aluminum pipes static and stable unlike studies J05, J06, and J10.
3. Study J08 does not require additional components or only consists of one main component.
4. When used as joint X, study J08 can only use 2 aluminum pipes unlike studies J09 and J10 which require 3 to 4 aluminum pipes.

Table 5. Search study analysis and proof of locking system.

<table>
<thead>
<tr>
<th>Code</th>
<th>System</th>
<th>Study</th>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Drat</td>
<td></td>
<td>- Easy joinery operation by rotating the aluminum pipe at the joint.</td>
<td>- It is difficult for a T-type joint where the pipe is in the middle of the component because the thread will be long.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Pipes can be removed from the joinery.</td>
<td>- The aluminum pipe must be threaded to enter the joinery.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- No need for additional components and materials.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Pipes can be stationary (static) and locked.</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Ball System</td>
<td></td>
<td>- Pipes can be removed from the joinery.</td>
<td>- Not too strong for furniture that has a lot of pressure because the pipe can push the ball into the joinery.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Easy joinery operation by pressing two buttons simultaneously.</td>
<td>- Don't know the system of pressing the button and entering the ball.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- No need for additional components and materials.</td>
<td>- The joinery component will be bigger because there is a pressing</td>
</tr>
</tbody>
</table>

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From Table 5 which shows an analysis of search studies and proof of the cross-system above, 1 study was selected out of 4 studies, namely the study with code S4 for the following reasons.

1. The system in study S4 can make aluminum pipes easily removable, unlike study S3 which uses glue so it cannot be removed.
2. The locking system in study S4 can make the pipe more static and stable because of the cross that penetrates the main components of the joint and the aluminum pipe.
3. The size of study S4 is not too large because it does not require a planting system like study S2.
4. The aluminum pipe in study S4 only needs to be perforated on both sides parallel to each other unlike in study S1 where the aluminum pipe needs to be threaded along the required area.
5. The method of use is not difficult, namely by pulling the crucifix out of the main component and then inserting the pipe into the joint, and then reinserting the crucifix into the main component.

Based on the results of the analysis of search studies and proving the shape of the joint and locking system, studies J08 and S4 were selected which formed the basic form of a joint system that has a flexible and solid form which can be seen in the Figures 1-3. The form is flexible in the sense that this joint system can be used in reverse, standing position, or sleeping position because the 4 upright sides have the same configuration shape, and the 2 top and bottom sides have the same configuration shape as well.

4 Conclusion and suggestions

The design of joinery for joint types I, L, T, X, and XYZ on aluminum pipes is a connection system design that can be used for joint types I, L, T, X, and XYZ for ¾ inch aluminum pipes with detachable joint
characteristics. The joinery types can be applied to knockdown furniture because its use does not require other tools.

Based on the results of the exploration of the shape and locking system that has been carried out, the designed joint system has a rectangular basic shape with one hole on each side, one as an area for inserting aluminum pipes, and 3 small holes on 4 vertical sides as areas for inserting crossbars to hold the aluminum pipe so that the aluminum pipe is locked. With a shape that has the same four upright sides, this joint system has the advantage of flexibility in its use, which can be used in a standing position or a sleeping position. A locking system that uses a cross-system with operation by removing the cross and reinserting the cross when the aluminum pipe has been inserted into the joint makes this joint not require any tools in its assembly. Based on the design results of joint systems I, L, T, X, and XYZ, it can be suggested that the size of the hole for the entrance area of the aluminum pipe and the hole for the cross-lock can be adjusted according to the size of the aluminum pipe used.

References

1. A. Anggito, J. Setiawan, Metodologi penelitian kualitatif (2018)