A Study for the Application of Steel Frames on a Traditional Wooden Fishing Boat

L Bochary1, M R Firmansyah1*, G Sitepu1 and S Asri1

1Departement of Naval Architecture, Engineering Faculty, University of Hasanuddin, Indonesia

*E-mail: mr.firmansyah@unhas.ac.id

Abstract. As its main material, specific timbers for supporting boat structure are required in the construction of traditional wooden fishing boat in Indonesia. The requirements for the specific timbers are vary such as it must be water resistant for ship skin planking and must be in the specific form for the boat frames in which the curvature will be different according to the specific curvature of each transversal boat section along the boat length. Currently, the required specific form of timbers for the boat frames are becoming difficult to be acquired especially in the midship area of the ship which requires extreme curvature. The difficulty to acquire the specific curvature form of frames as required have threaten the sustainability of wooden boat construction process in Indonesia. Hence, an alternative material for replacing the wooden material for boat frames is needed. The requirements for the alternative material are as follows; it must be easy to be formed according to the boat transversal section form along the boat length and must be strong enough to support the strength of the wooden boat hull. This research is conducted in order to analyse the feasibility of steel frame application for replacing wooden frame in the construction of traditional wooden fishing boat. Some alternatives of different steel frame dimensions with specific profile forms are analysed to determine the appropriate steel frame construction for certain type of wooden fishing boat. In the end, a recommendation of the steel frame dimensions for replacing wooden frame on a certain traditional wooden fishing boat is proposed.

1. Introduction

Wooden boat is a boat which almost all of its constructions are made from wood. The construction of wooden boat in Indonesia have been conducted since hundred of years ago. The ability to build the wooden boat have been inherited by the craftsmen ancestor generation by generation. Up to several years ago, wooden material for the construction of wooden boat is relatively easy to obtained as plenty of forests in Indonesia. But as the deforestation in some forest in Indonesia, wooden material as the main material for wooden boat is becoming difficult to obtain. Hence, the price for the material has become expensive [1] and there is no alternative material which been studied yet for replacing the wooden material in the wooden boat construction. If the condition continuously happens, some day in the future, the wooden boat can not be constructed in Indonesia anymore.

In order to support the sustainability for wooden boat construction in Indonesia, some efforts need to be done to find an alternative material for replacing wooden material in the construction of wooden boat. The alternative material must be on certain part of the wooden boat construction to maintain the specific form of the wooden boat.
In this research, wooden frame in the wooden boat construction have been selected to be analysed. Steel material have been chosen as an alternative material for frame construction to replace wooden frame in wooden boat [2]. The selection of frame construction in this research as it consumes significant amount of cubic volume of wooden material. Besides, this form of construction is the most difficult form of wooden boat construction to obtain.

2. Current Traditional Wooden Fishing Boat Frame Construction

Frame in any boat construction is the most important part of the construction since it being the skeleton to support the boat body and at the same time support the boat longitudinal strength. Frame in a wooden boat construction is installed on the boat transversal side along the boat length from keel to up to the side of the deck beam (Figure 1) [3]. In wooden boat construction, the shell plank as well as the inner shell plank are attached to the wooden frame [4].

![Figure 1. The construction of wooden boat](image)

Unlike frames on the construction of steel ship, frame on a wooden boat construction is made from single frame and it is continuously constructed from starboard to portside according to the boat body curvature but they are attached and connected through wooden keel. The distance between frames in the wooden boat construction is measured between wooden axes and it is determined based on the shipping area of the respective wooden boat [5].

Wooden frame is generally made from naturally curved wooden as it will support the whole boat strength [6]. But sometimes, the wooden frame must be connected in order to get the required wooden frame for the boat construction [7]. Though, priority is given to the continuous wooden frame construction. Hence, as the tight requirements, the wooden frame is relatively difficult to obtained as required. On the other side, the need for the specific wooden frames is a must [8].

In order to solve this problem, an alternative material for wooden frame is required. The selection of steel frame for replacing the wooden frame become the most rational selection for some reasons such as it easy to get as steel frame can be found everywhere, it is stronger then wooden material, it is easy to be formed according to the curvature of the wooden boat body and it is more cheaper to compare with wooden frame price [9].

3. Feasibility of Steel Frame Application for Replacing Wooden Frames

Object for this research is traditional wooden fishing boat with 30 GT of its capacity. Data of the boat to be collected for this analysis consist of wooden boat main dimension as well as its construction dimension such as wooden frame, shell plank, inner shell plank and boat keel. The location for data collection is in a traditional wooden boayard in Galesong Kota village, Takalar regency. The boat at the time of data collection is still under-construction as can be seen in Figure 2.
The main dimension of the 30 GT of wooden boat can be seen in Table 1 below.

**Table 1.** The main dimension of the 30 GT of traditional wooden fishing boat

| Parameter                                      | Value       |
|-----------------------------------------------|-------------|
| Ship tonnage                                   | 30 GT       |
| Length overall (LOA)                          | 2280 cm     |
| Length between perpendicular (LBP)            | 1850 cm     |
| Breadth                                       | 510 cm      |
| Height                                        | 180 cm      |
| Draught                                       | 100 cm      |

3.1. The boat construction dimension

In this research, the main boat construction data to be collected is its keel, frame, shell plank, inner shell plank, distance between frame as well as distance between inner shell plank.

3.1.1. Frame dimension.

Wooden boat frame was measured for 10 samples of wooden frame dimension. As traditionally formed for the wooden frame construction, there is an inconsistency of wooden frame dimension along the frame. Hence, in the wooden frame measurement process, the frame was divided into 4 zones of measurement as can be seen in Figure 3. Zone A is the farthest from the boat keel while zone D is the closest from the boat keel. The average value of the wooden frame dimension will be the dimension of the wooden frame.

![Figure 3. The measurement of wooden frame dimension](image)
The result of the measurement can be seen in Table 2 below.

| Zone | No | Wooden boat 30 GT |
|------|----|-------------------|
|      |    | Width (cm) x Height (cm) x Distance between axis |
| A    | 1  | 9.7 x 11.8 x 39.9 |
| B    | 2  | 9.4 x 12 x 39.9  |
| C    | 3  | 10.6 x 13 x 39.5  |
| D    | 4  | 10.6 x 13.1 x 40   |

3.1.2. Wooden inner planking dimension.
The dimension of the wooden inner planking for 30 GT of traditional wooden fishing boat is 20 cm wide and 5 cm for its thickness (Figure 4). The distance between inner planking is about 50 cm average (Table 3).

![Figure 4. The wooden inner planking measurement](image)

**Table 3.** The dimension of the inner planking and the distance between

| No | Wooden inner planking dimension 25 x 5 cm | Distance between inner wooden plank |
|----|----------------------------------------|-----------------------------------|
|    | Width (cm) x Thickness (cm) x Distance between axis |
| 1  | 25.018 x 4.85 x 50.05                   |

4. Wooden Boat Keel Dimension
Keel for the boat is made from the big and long beam. The boat keel measurement is conducted in some parts of the boat keel as the inconsistency of the boat keel dimension. The measurement process of the boat keel dimension can be seen in the Figure 5 and the result of the measurement can be seen in Table 4.
Figure 5. The measurement process of the boat keel

Table 4. The dimension of the 30 GT traditional wooden fishing boat

| Boat   | Average height (cm) | Average width (cm) |
|--------|---------------------|--------------------|
| 30 GT  | 20 ± 0.3            | 17 ± 0.5           |

4.1. Shell plank dimension
The process of the wooden boat shell plank measurement process can be seen in the Figure 6 while the result of the measurement can be seen in Table 5.

Figure 6. The measurement process of the boat shell plank

Table 5. The dimension of the wooden boat shell plank.

| Boat   | Average thickness (cm) | Average width (cm) |
|--------|------------------------|--------------------|
| 30 GT  | 5 ± 0.3                | 20 ± 0.5           |

5. Modelling Wooden Frame Structure
Boat construction data to be used in the modelling process is the data from the boat construction measurements in the midship part of the boat. The selection of this construction part is because midship part of the boat is bear the biggest load in the transversal construction of the boat [10]. Data obtained from the measurement process then translated into two and three dimensional of drawing as can be seen in Figure 7 below. Modelling uses $x$ axis which refer to ship breadth, $y$ axis which refer to ship height and axis $z$ which refer to ship length [11].

Figure 7. The transversal midship construction of the fishing boat
5.1. Load calculation on the boat
The load to be applied on the boat construction in this model is calculated based on the Indonesian Bureau Classification (BKI) rules Vol. II 2016 [12] for load calculation on a ship. It consists of two types of load which works on ship which are boat side and boat bottom load.

5.2. Boat side load
Side load according to BKI [12] rules consist of two directions of side load which are sea wave from the front and sea wave from the side of the boat. The result of the calculation based on the formula in this rules can be seen in Table 6 below.

| Height | Sea wave from the front (N/mm²) | Sea wave from the boat side (N/mm²) |
|--------|---------------------------------|------------------------------------|
| 0      | 1.276 E-02                      | 1.455 E-03                         |
| 0.5    | 9.134 E-03                      | 1.296 E-03                         |
| 1      | 5.512 E-03                      | 9.099 E-03                         |
| 1.5    | 5.249 E-03                      | 8.271 E-03                         |
| 1.8    | 5.103 E-03                      | 7.844 E-03                         |

Based on the Table 6, the biggest side load being applied to the boat body is both when the sea wave is coming from the front and from the boat side at the height of 0 which is on the lowest part of the boat body.

5.3. Boat bottom load
Bottom load according to BKI rules consist of two directions of bottom load which are sea wave from the front and sea wave from the side of the boat. The result of the calculation based on the formula in this rules can be seen in Table 7 below.

| Height | Sea wave from the front (N/mm²) | Sea wave from the boat side (N/mm²) |
|--------|---------------------------------|------------------------------------|
| 0      | 2.755 E-03                      | 4.549 E-03                         |
| 0.25   | 5.255 E-03                      | 7.049 E-03                         |
| 0.5    | 7.755 E-03                      | 9.549 E-03                         |
| 0.75   | 1.025 E-02                      | 1.204 E-02                         |
| 1      | 1.275 E-02                      | 1.454 E-02                         |

Similar to the side load, the biggest bottom load being applied to the boat body is both when the sea wave is coming from the front and from the boat side at the lowest part of the boat body.

5.4. Condition of the loading and restraint
The loading pressure is then being applied to the boat body which is based on the side and bottom load as previously calculated. The pressure on the boat body as the result of the calculated load can be seen in Figure 8 below.
The load to be applied is the resultant load of the boat side and bottom load. The distribution load only be applied in the direction of the plane normal angle and hence, the load resultant can be found on the normal axis of the plane. The result of the load model can be seen in the following figure (Figure 9).

![Figure 8. Distribution of pressure load on the boat wooden plank](image)

**Figure 8.** Distribution of pressure load on the boat wooden plank

The result of the load on normal direction of the area

6. **Recommendation of Suitable Steel Frame Dimensions for Replacing Wooden Frame**

6.1. **The selection of steel frame dimension**

The form of the steel frame to be applied to replace the wooden frame in the construction of the wooden fishing boat is based on the Larengi [13] research which recommend the T form of the steel frame. The selection of the T from for the steel frame is based on the consideration of some aspects such as its form, easy to be constructed, ease for binding the frame to the boat shell plank and some other criteria. The T form of the steel frame construction can be applied on the boat shell plank by following the curvature of the boat body while the binding process using some nuts and bolts which is bound with the shell plank (Figure 10) [2]. For inner shell plank stand, some attachments according to the distance of the inner shell plank have been applied.

![Figure 10. Model of the steel frame to be used](image)
The form of the steel frame to be used to replace the wooden frame in the construction of the wooden boat is according to frame form in Figure 10. The dimension of the steel frame is conducted by calculating its stiffness which is equal to the wooden frame or $EI_{steel}$ is less then or equal to $EI_{wood}$. The profil dimension is calculated on trial and error method with the constraint of width and the height of the steel frame is not more than the width and the height of the wooden frame.

6.2. Deflection

Response structure analysis of the frame was conducted in order to identify its deflection. Deflection can be obtained by simulating the load on the structure using some alternatives of the steel frame. The deflection to be analysed is the deflection on the direction of x axis and y axis. Deflection from z axis can be ignored as the value of the deflection is very small and its not directly affect the structure [14]. The total deflection on the frame can be seen in Figure 11. Frame to be observed is frame located in the middle of the construction model as the result of the side load and bottom load. The observation is including the inner shell plank, shell plank as well as two or three frames next to the main observed frame.

![Figure 11. Total deflection on the model](image)

In Figure 11, the colour determined the value of the deflection. The red colour shows the biggest deflection occurred to the construction model. The maximum value of the deflection for 30 GT of wooden fishing boat can be seen in Table 8. The result of the deflection then can be compared between wooden frame and steel frame and it can be seen in Table 9.

| Table 8. Maximum deflection value in x axis direction in mm |
|------------------------------------------------------------|
| Boat | Frame | $\delta$ | Distance from CL |
| 30 GT | 0.979 | 2325.1 |

| Table 9. Result of the comparison of steel frame and wooden frame dimension |
|----------------------------------------------------------------------------|
| Boat | 30 GT |
| Wooden dimension | 121 X 100 mm |
| $E_{wood}$ | 11.866 Mpa |
| $I_{wood}$ | 14.763,008 mm$^4$ |
| $E_{steel}$ [15] | 206.000 Mpa |
| $I_{steel} = \frac{Al_{wooden}}{E_{steel}}$ | 0.65 X 8.50 E+05 mm$^4$ |
| $I_{steel} : trial and error$ | 5.73 E+05 mm$^4$ |
| Steel frame dimension | 100X80X8 mm |
| $\frac{E_{steel}}{AI_{wooden}}$ | 0.67 |
Based on the analysis, the steel frame dimension to replace the wooden frame in the construction of the wooden 30 GT fishing boat is 100 mm x 80 mm x 8 mm.

7. Conclusion
The use of steel frame for replacing wooden frame on a wooden boat construction shows promising result. In this study, steel frame was analyzed based on the characteristics of wooden frame in the construction of wooden boat. Some steel frame dimension was simulated in order to find its behaviour which is closest to the behaviour of wooden frame. The result shows that, when using steel frame dimension which have the same value of Elsteel/EIwood, deflection on steel frame is 35% smaller for 30 GT Wooden boat. It means that steel frame is strong enough to carry any load to compare with wooden frame. The dimension of steel frame which appropriate for 30 GT wooden boat is 100 x 80 x 8 mm.

References
[1] Ayuningsih, Dewi. 2007. Techno economic for the wooden vessel construction on a traditional wooden shipyard in Gebang village, Cirebon, West Java. Institut Pertanian Bogor. Bogor [in Bahasa].
[2] Bochary, L. dan Larengi, F, 2012, An alternative for the use of steel frame on 30 GT wooden vessel construction. Journal Riset Teknologi Kelautan. Vol 10. No. 2, pp 121-272. Makassar [in Bahasa].
[3] Biro Klasifikasi Indonesia. 1992. Guidance for building motorized sailing ship. Indonesian Classification Bureau, Jakarta [in Bahasa].
[4] BSN. 2013. Design specification for wooden construction. Badan Standar Nasional. Jakarta [in Bahasa].
[5] Rauf, A. M., dan Chaerunnisa, A. 2003. The development of a method for traditional wooden boat construction in Bulukumba regency. Lembaga Penelitian Pengembangan Masyarakat Universitas Hasanuddin, Makassar [in Bahasa].
[6] Hunggurami, Elia, Sudiyo Utomo, Beddy Y. Messakh. 2016. Identification of strength reference of commercial wooden type in Kupang city based on SNI 7973:2013. Undana. Kupang [in Bahasa].
[7] Karim, Abdul Azis , Mabsyur H., A. Haris Muhammad. 2011. Study for the dimension and model connection of wooden boat construction in a traditional wooden boat shipyard in Bulukumba regency. UNHAS. Makassar [in Bahasa].
[8] BKI. 1996. Rules for wooden boat. Biro Klasifikasi Indonesia. Jakarta [in Bahasa].
[9] BKI. 2014. Vol V Rules for Materials. Biro Klasifikasi Indonesia. Jakarta [in Bahasa].
[10] Gerr.dave. 2000. Boat Strength for Builders, Designers, and Owners. International Marine. Camden.
[11] Pinem, Daud. 2013. ANSYS Mechanical system analysis. Wahana Ilmu Kita. Jakarta [in Bahasa].
[12] BKI. 2016. Vol II Rules for domestic hull. Biro Klasifikasi Indonesia. Jakarta [in Bahasa].
[13] Larengi, Farid. 2012. An alternative for the use of steel frame on a 30 GT wooden boat construction. Laporan Penelitian. Fakultas Teknik UNHAS. Makassar [in Bahasa].
[14] Infometrik. 2009. Basic concept of Finite Elemen Method. Online. Accessed: http://www.infometrik.com/2009/07/konsep-dasar-finite-element-method/ . 11 Maret 2017 [in Bahasa].