

A Study on the Restoration of Hull Shapes in the Early Goryeo Dynasty: Focusing on the Case of Sibidongpado Shipwreck

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ABSTRACT

The Goryeo Dynasty (918–1392 CE) was a period when marine activities were very active centering on Byeokrando. The Sibidongpado and Wando shipwrecks are important data that can show marine activities in the early Goryeo Dynasty. It is characteristic that most of the accompanying artifacts are celadon produced in the Haenam region, and that curved longitudinal member was confirmed in the hull structure. To investigate the shape variables necessary to identify hull shape of the Sibidongpado shipwreck the shape and structure were reviewed from a shipbuilding engineering point of view. First, through 3D scanning of the remaining hull such as the bottom plate, curved longitudinal member, and outer plate, the main dimensions were calculated, and 19 shape variables necessary for hull restoration were extracted. Next, the data of each part of the ancient shipwrecks of similar period was made into statistics, and the geometric dimension ratio was applied, or each pre-calculated shape variable was defined based on the modeling data. Based on the defined shape variables, the hull shape was restored, and the corresponding displacement and restorability were derived, and the ship restoration was attempted from the point of view of shipbuilding engineering. Finally, based on the data of the excavated ancient shipwreck, the structure of each part of the ship was reproduced in 3D shape. It is not easy to restore the original form of an ancient ship based on the limited remaining hull fragments and historical sources. As ancient shipwrecks are an essential element in identifying marine activities of the time, future research is expected.

Keywords: Goryeo Dynasty, ancient ship, Sibidongpado shipwreck, restoration of hull shape

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INTRODUCTION

In Korea, from the underwater excavation of Sinan shipwreck artifacts in 1976, and to the most recent Daebudo no. 2 shipwreck, a total of 16 ancient shipwrecks have been identified in Korean waters. Ten of these ancient ships are Goryeo Dynasty shipwrecks, along with celadon, grains and salted fish, and coal spoons.

Sibidongpado and Wando shipwrecks are important data that can show marine activities in the early Goryeo Dynasty (918–1392 CE). It is characteristic that most of the accompanying artifacts are celadon produced in the Haenam region, and that curved longitudinal member was identified in the hull structure. It is not easy to presume the overall scale only with the limited remaining hull fragments, which are mainly concentrated on the bottom of the ship. The shape variables necessary to identify the hull shape of the Sibidongpado shipwreck were examined from a shipbuilding engineering point of view.

The process of 3D scanning and calculating major dimensions of the remaining hull, such as the bottom plate, was reviewed, and 19 shape variables required for hull restoration were extracted and data of each part was made into statistics or each shape variable was defined based on geometric dimension ratio and modeling data. We attempted restoration of the hull shape according to shape variables, deduction of displacement and stability through hydraulic calculation, review of the hull shape from the point of view of shipbuilding engineering, and 3D shaping.

CALCULATION OF MAJOR DIMENSIONS BY 3D SCANNING

The remaining hull found in the excavation investigation of Sibidongpado shipwreck is a total of 11 including six bottom plates in three rows, two curved longitudinal members in portside and three bow

materials, showing the flat bottom structure of a traditional Korean ship (National Maritime Artifacts Museum 2005, 50-66). For the bottom plates, the two central bottom plates were connected by a concave-convex tenon joint method, and the left and right bottom plates were connected by a shiplap method. It is highly likely that one member was added to the center bottom plate, and there must have been more materials connected butt-to-butt on the left and right bottom plate. As for curved longitudinal member, only two members of the first stage were recovered from the portside. We assume two stages of curved longitudinal member. The bow members are in three fragments, vertically butted together and fixed with a long line, and on the left and right sides, grooved jaws that meet the outer plate have saw tooth markings.

For these 11 members, 3D scanning was conducted to estimate the shape of the lost parts of the shipwreck after securing the exact size, connecting methods, and data about the hull shape of the excavated hull pieces. Individual hull pieces are photographed at 24 to 26 locations with a broadband scanner and photogrammetry, and the acquired data are individually made into surface modelling through post-processing such as noise removal, matching, and mapping, and the merged modeling data was regenerated. After that, the image of the scan data was used to calculate the main dimensions and the basic shape of the ship by picking the inner and outer lines, patterns, cracks, and damaged parts.

EXTRACTION AND DEFINITION OF SHAPE VARIABLES

For the Sibidongpado shipwreck 3D scanning, variables were selected from a statistical point of view using data from ancient ships of a similar age.

As the main variables constituting the shape of the shipwreck, the following 19 variables were selected, and among them, the length, bottom width, and bow length of the ship were fixed to the values of the excavated hull pieces from reports of Mado no. 1, Anjwado, and Wando shipwrecks.

Table 1. Main shape parameters of Sibidongpado shipwreck

Subject	Length (LOA)	Beam	Depth	Deadrise angle	Bottom length	Bottom width	Bow angle	Stern angle
Value	14.5 m	5.41 m	2.45 m	26°	11.2 m	1.81 m	21.67°	14.67°
Subject	Height of a bow structure	Height of a tail structure	Angle of a bow structure	Angle of a tail structure	Length of a bow structure	Length of a tail structure	Width of a bow structure	Width of a tail structure
Value	2.84 m	2.58 m	68°	45°	1.76 m	2.48 m	1.18 m/1 m	138 m/1.07 m
Subject	Angle of hog sheer	Displacement		Waterline				
Value	0.94°			1.25 m				

The shipwreck is estimated at 14 to 15 meters (m) (NRIMCH 2005). As for the width and the depth of the shipwreck, they were estimated at geometric dimension ratios at 2.45 m respectively.

The deadrise angle is the dimension of the slope from the bottom plate to the side of the ship. Sibidongpado shipwreck has a large angle of deadrise as there are two curved longitudinal members. As the exact dimensions of the second stage of curved longitudinal member is not identified, the deadrise of the bottom plate and curved longitudinal member was identified.

The bottom plate is identified as the straight-line distance from the part where the bow material and bottom plate are connected to the part where the stern is connected. It is difficult to identify the exact size of the Sibidongpado shipwreck, as the bow and stern parts are lost, although three rows of bottom plates were excavated. In particular, in the process of precise measurement and hull restoration, traces of mortise were confirmed at the stern end of two central bottom plate members, confirmation that the central bottom plate was composed of three members.

The bottom length of the remaining hull is about 6.8 m from the bow end of center bottom plate of one member to the stern end of left bottom plate of two members. However, there is one more central bottom plate, estimated to be larger. Therefore, based on the length of a ship and the width of the bottom of the bow member, installation angle and height of the bow member and the stern member, the profile of the side of the bottom plate was restored, and the length of the bottom plate was estimated 11.2 m.

The bow and stern angles are from the baseline to the part where the bottom plate touches the bottom of the bow or stern members. The value is not uniform because the bottom plate does not extend at an exact angle from the baseline to the bow and stern members but is bent round. To estimate the angles of bow and stern, the values of Mado no. 1, Anjwado and Wando shipwrecks, whose structures remain, were made into statistics and $21.67^{\circ}/14.67^{\circ}$ were applied.

The stem length is estimated at 1.65 m from 3D scanning results. Whereas the stern length is estimated at 2.5 m. For this latter length we calculated the stern angle, stern member angle, and stern height (see table 1). As the dimensions of the upper and lower surfaces of the bow and stern members are different, they were defined separately. The widths of the top and bottom of the bow members are 1.18 m and 1 m, and the widths of the top and bottom of the stern members are 1.38 m and 1.07 m, respectively.

The angles of bow and stern were defined as the angle between the bow and stern members and the baseline. It was estimated based on the V-shaped processing traces on the bottom of two remaining members of the stem and the value of Mado no. 1, and the angle of the bow material is 68° . In order to estimate the angle of stern member, the data of Mado no. 1, Anjwa, and Dalido shipwrecks were statistically applied and resulted in the value 45° .

As the heights of bow and stern members were estimated through the height ratio of the core and bow and stern members of Mado no.1 and Dalido shipwrecks, and the heights of the Sibidongpado shipwreck are 2.83 m and 2.34 m, respectively.

The hog sheer angle is the ratio between the curve formed by the upper deck and the distance from the bow to the stern, or LOA, when the hull is viewed from the side. Among the ancient shipwrecks excavated underwater, the ship whose hog sheer angle can be measured is the Mado no. 1, which is about 0.95 m. The Sibidongpado shipwreck is estimated with similar dimensions.

Draft is a dimension representing the vertical distance from the position where the ship's midship touches the water surface to the bottommost part of the ship when the ship is afloat. The draft was determined from the bottom plate to the modeled side profile at 1.25 m.

It means the weight of the ship, which indicates the weight of the water displaced when the ship is afloat. When the weight of the ship and the load are unclear, the displacement can be estimated according to the draft. We use the draft.

REALIZATION AND REVIEW OF SHAPE OF SIBIDONGPADO SHIPWRECK

Based on the major dimensions above we produced a 3D model using CATIA V5.

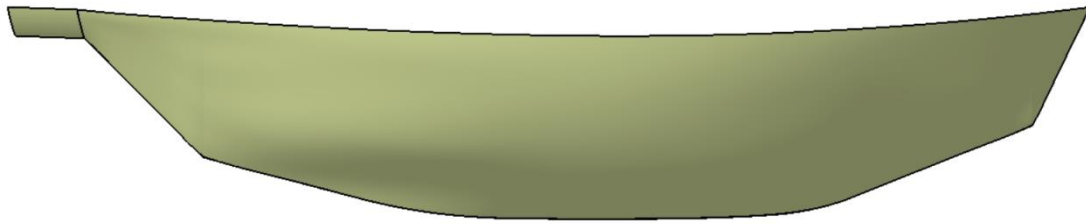


Figure 1. Result of restoration of hull shape of Sibidongpado shipwreck

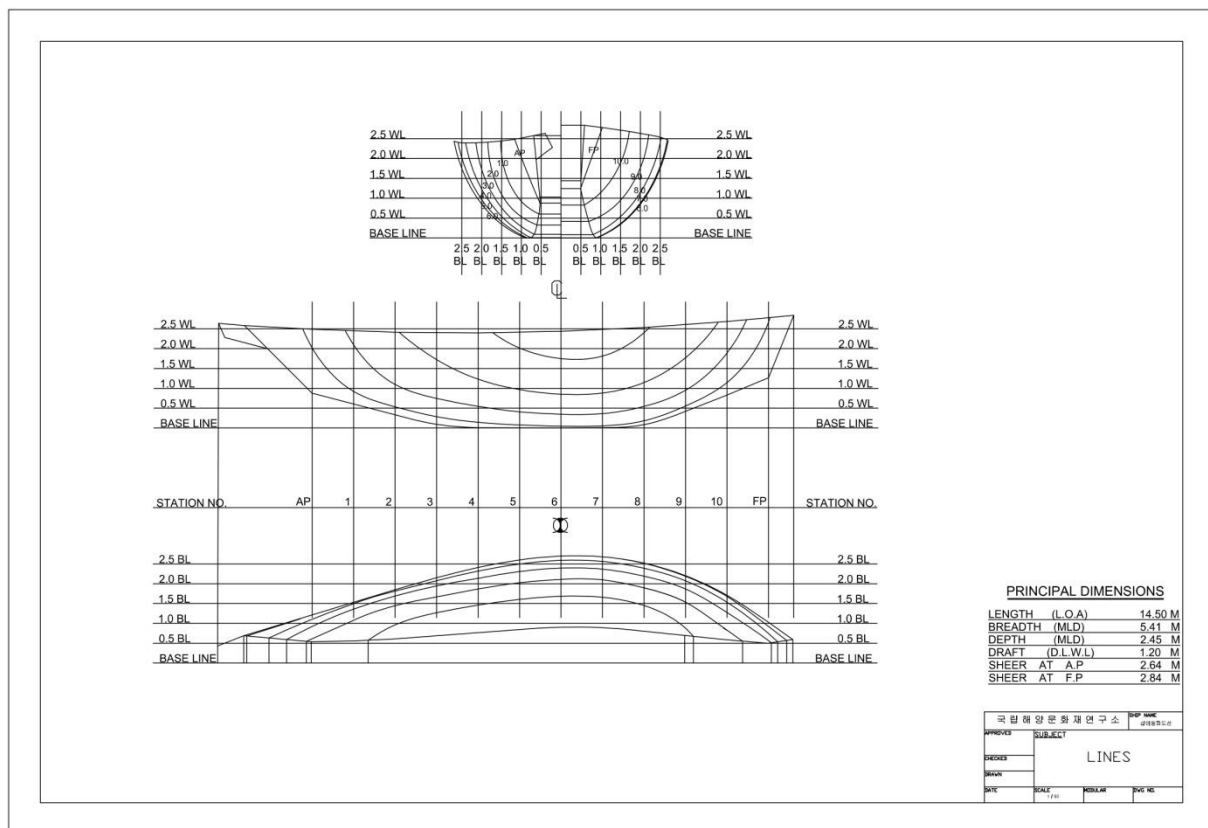


Figure 2. Shape diagram of Sibidongpado shipwreck

Hydrostatics calculations was performed to estimate displacement according to draft. This calculation estimates various linear coefficients and hull characteristics. The hydrostatics curve from the baseline to the range including the draft of 1.25 m are provided in figure 3.

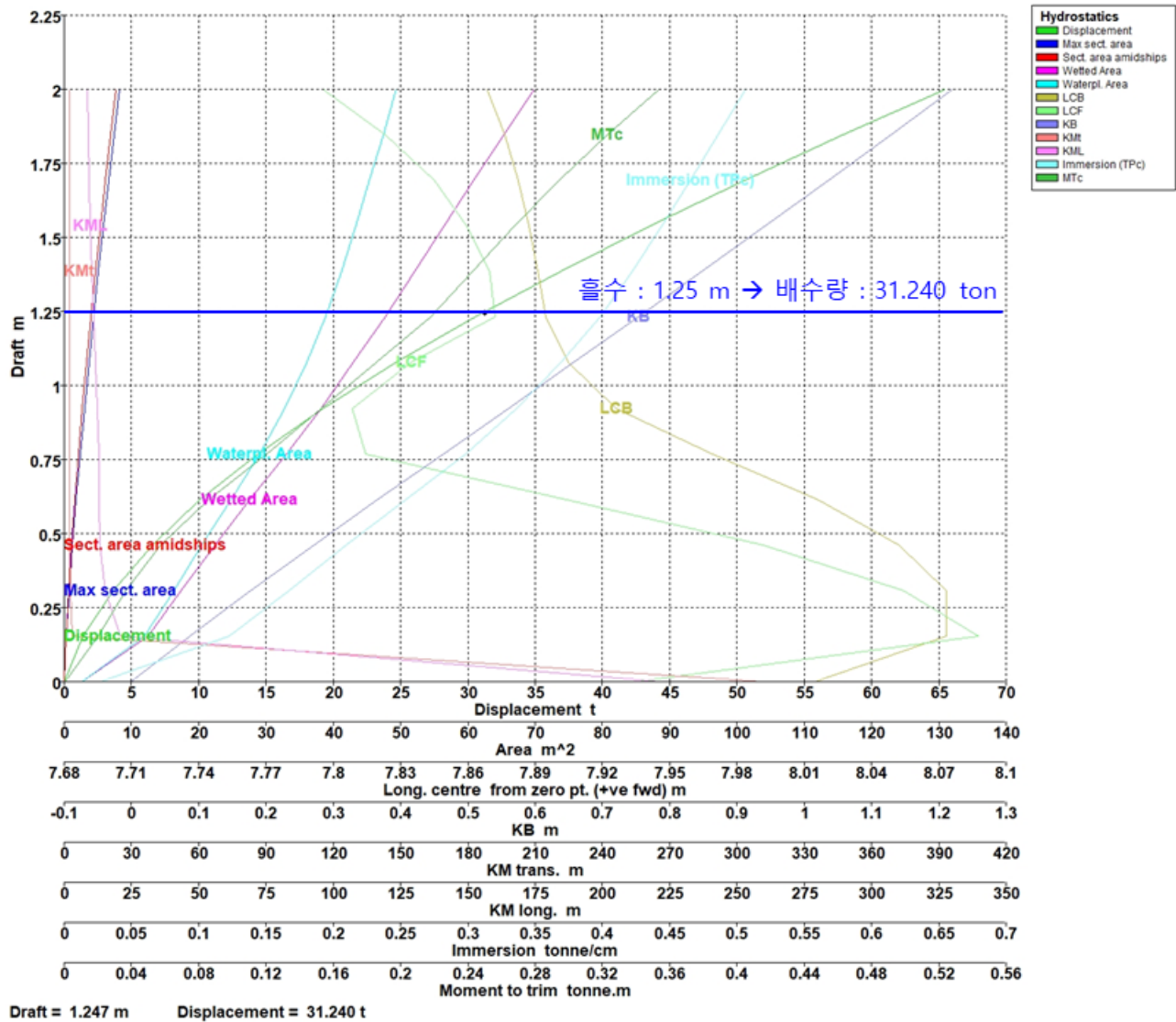


Figure 3. Hydrostatics curve of Sibidongpado shipwreck

CONCLUSIONS

Sibidongpado shipwreck is an example of marine activities in the early Goryeo Dynasty (918–1392 CE). Most of the accompanying artifacts are celadons produced in the Haenam region, and that curved longitudinal member was identified in the hull structure. Nineteen shape variables necessary to identify the hull shape and structure were examined.

Three-dimensional scanning was performed on the excavated hull, including a bottom plate. Statistical data of each part of ancient ships belonging to the similar period of the Sibidongpado shipwreck, or 19 shape variables necessary for restoration of the shape of a ship, were extracted and defined based on geometric dimension ratio and modeling data. Based on the defined shape variables, the Sibidongpado shipwreck hull shape was estimated.

As a result, the bottom plate of the structure of each part of Sibidongpado shipwreck shows a flat bottom structure like other traditional Korean ships, and the bow and stern show a gently curved line. The bottom plate is composed of three pieces in a row, and the center bottom plate is connected by a tenon joint, and the left and right bottom plates are connected by a butt joint and a shiplap method. The ‘L-shaped’ curved longitudinal member is raised in two stages with a chin cut out on the outer upper surface

of the bottom plate, and a hole connected to the bottom plate is made in the part where it rests on the chin, and it is joined with a pisak. Each stage of curved longitudinal member consists of three pieces and is connected by a shiplap method.

The bow is structured with three members vertically, and on the left and right are sawtooth-shaped grooves. The shape of the lower part connected to the bottom plate was processed into a 'V' shape, and a concave jaw was cut out on the upper surface of the bottom plate, and the bow member was erected at an angle of 68°. Excluding the curved longitudinal member, all the outer plates are raised in five layers, and each layer is composed of three to four members. lateral outer plates curve gently up toward the bow and stern. From a plan view the central part was about three times wider than the bow and stern. The stern structure was formed by removing concave chins on the inside of the outer plate and the upper surface of the end of the bottom plate, with plates horizontally raised.

As the garyong was identified in the curved longitudinal member that came out, the interior of the ship was divided into four sections by referring to the garyong spacing. Wando and Dalido shipwrecks shown in port side curved longitudinal member 1-1 and 1-2. Chagaryong was installed on the first and third layers of the outer plate, and the curved longitudinal materials and the rest of the outer plate were reinforced with a garyong and a yoke. As the upper structure has been lost, it is not clear to what extent the deck was installed, but it is assumed that it was installed in the space for sailors' activities that are essential for navigation, and basically protects cargo inside the ship. Therefore, the deck was installed in the stern space where the boatman manipulates the key, and in the central part of the hull and the bow space where the sail and anchor can be raised and lowered.

An anchor is essential in the process of anchoring and departing a ship, and a lantern that raises and lowers it too. A cylindrical member thought to be a lantern tube, and a pedestal supporting it, were excavated. The pedestal was connected to the structural wood connecting the square groove on the inner side of the bow member and the garyong. As for the sail, a wood groove on the center bottom plate 2 and a mast structure from Mado no. 3 were applied. A Dang-a horn was installed on the chagaryong on the third layer of the outer plate, this holds the mast in the wood groove. The mast was likely located in front of the garyong in the wood groove of the curved longitudinal member. Through the Okchi structure that goes inside the hull, based on the angle of the stern and the structural stability of a key, the structure and shape of the ship in the early Goryeo Dynasty were identified.

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