

A Study on the Structure of the Fourteenth Century Chinese Merchant Ship (Sinan Shipwreck)

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ABSTRACT

Further research on Sinan shipwreck structure is required. The questions raised by Lee Cheol-han and Lee Chang-eok in *Report on Sinan Ship Conservation and Restoration* and those in the new edition of *Sinan Shipwreck* are summarized in this paper. They are summarized as follows: First question is about the understanding of bar keel; second is the combining structure and inclination angle of bar keel and plate stem; third is whether additional side plate was possible and major measurement of hull and molded depth; fourth is whether to consider the deck side structure as deck as before; fifth is the recognition of the sectional shape of the hull center - if the four questions above are solved; sixth is whether oars were installed; seventh is the other mast legs and liquid tank. To address these questions, I first organized terminology and corrected incorrect terms, I then examined the literature on analysis of structural characteristics. For methodology, my lens was that of a professional shipbuilding engineer. I considered major structures in the excavation reports, conservation and restoration reports, and original shape estimation report. I added missing structures that have come to light since these reports were produced. I aim to identify the comprehensive structure of ancient Korean merchant ships for comparative studies with Chinese and Japanese ships and development of ships by period.

Keywords: Sinan shipwreck, keel, floor, shell plating

INTRODUCTION

Sinan underwater excavation (Office of Cultural Properties of Ministry of Culture and Information 1983; 1984; 1985; 1988; National Maritime Museum 2004; National Research Institute of Maritime Cultural Heritage 2018) began on August 20, 1975 when Chinese ceramics (six items including a celadon vase) were caught by fisherman Choi Pyeong-ho's net. Excavation was conducted by the Cultural Heritage Administration in cooperation with the Navy for nine years from 1976 to 1984 CE.

Sinan shipwreck sank 4 km away from Imjado Island and Hoedo Island in the offshore of Heodo-myeon, Sinan-gun, Jeollanam-do, likely due to maritime weather and environmental factors while sailing from China to Japan. Sinan shipwreck is a V-shaped pointed bottom type that was produced a lot during Song and Yuan Dynasties (960-1368 CE) of China. The coins and copper mirrors arranged in the Big Dipper in the middle of the keel followed the traditional ritual for a safe return and wellbeing of ships in China, this detail leads us to presume it is a Chinese trade ship. In addition, the hull is made of Krempf's Pine and *Pinus massoniana*, red pine and black pine; and internal structure is *Cinnamomum* spp; fendering apparatus is *Cunninghamia lanceolata*. The analysis of such materials showed that it was a Chinese trade ship made about 700 years ago (National Maritime Museum 2004, 16-25).

In 1981, Kim Jae-geun conducted study on Sinan shipwreck by comparing the structure of ships of Goryeo and China and he presented the hull structure and specifications and tested his ideas by making miniature model. In 1989, Lee Cheol-han examined the process of making it to restore original shape of hull of Sinan shipwreck and its significance. In 2004, Kim Yong-han classified hull pieces and identified structural characteristics for shape and restoration scale of Sinan shipwreck. He compared and reviewed literature and data on old Chinese ships. In 2004, Choi Hang-soon analyzed Sinan shipwreck by making 3D images to see displacement, weight, deadweight, resistance performance and structural strength from the perspective of shipbuilding engineering. This presented major specifications of Sinan shipwreck. In 2004, NRIMCH treated hull pieces for conservation, restored remaining condition and published reports. Further studies on 3D precision measurement of restored Sinan shipwreck in 2018, 3D printing model, basic and detailed design, ship engineering analysis, and model to estimate original shape. However, despite all the research, the questions raised by researchers about structure of Sinan shipwreck are not clearly answered.

REVIEW ON THE STRUCTURE OF SINAN SHIPWRECK

The structure can be divided into four: main body, reinforcement, design and auxiliary.

Main body

Keel

Keel is the most important structure of the hull. In likeness to the spine in human body, it is composed of three connected materials. The way of connecting three materials is scarf joint for mutual joint and in order to harden the scarf joint, wedge was used. In the joint of keel, it has a hole for inserting coins indicating that it is a Chinese ship and a shallow circular hole was dug between bow and center keel to put circular mirror made of cupronickel. Nine holes were made on horizontal section of the central and stern keel and bronze coin called Tai Ping Tong Bao was put in each hole and covered with wooden stopper. There is elevated structure with floor to separate the areas on the top surface of keel. In particular, the keel at the center, out of three keels, have elevated central part with slight curve at the edge downwards. It is designed to improve the navigation performance intentionally rather than external shock during sailing or wreckage.

Floor

Floor is a structure located between the keel and bulkhead. The shape is same as bulkhead but it is thicker. Because thicker material was used, the bulkhead and frame are placed on the floor and connected each other. In addition, frame is installed to divide the front and back sides based on bulkhead. The frames are installed on the front side from I to IV (to the direction of bow) and on the back side from V to VII (to the direction of stern). The way of connection and fixing was traditional Chinese style to strengthen the structure by placing floor at the groove on the top of keel. One of the important features of floor structure is a square hole at the center that prevents the water inflow between compartments. This structure applies sophisticated shipbuilding technology to prevent sinking due to flooding by blocking holes. However, the excavation report mentioned this structure as 'waste water corridor' where water accumulated on the floor passes. Therefore, additional study is required.

Transom floor

Transom floor is a structure that is located at the stern and connected to the keel. The shape of the first stage of stern has the same floor type and connection structure but it does not have square hole at the bottom center. However, it has elevated structure on a half of the top surface to install floor. The member of the hull is recorded as stern frame structure. The research shows that the stern frame structure is installed on the floor like bulkhead, it is reasonable to consider the structure installed at the stern area on top of keel as transom floor and the thinner plate than lower stages was placed on top of the floor.

Garboard strake

Garboard strake is located between keel and the first stage of shell plating. Its shape is similar to that of shell plating but its thickness is about 20 cm, which is significantly thicker than shell plating whose thickness is 12 cm. Keel, floor, and garboard strakes are connected by placing the keel whose sectional shape is square and L-shaped groove is made on both sides of the top side to attach garboard strake. The floor is attached to the top of the keel and inside of the garboard strake. For fastening each member, iron bar was used to maintain enough strength.

Bulkhead

Bulkhead is composed of seven bulkheads and eight windows from the shell plating (it is estimated to be deck structure at that time) with eight compartments in total. Bulkhead is a major member that composes frame of the hull, serving as the basis for ship shape. It serves as the fixing framework for the assembly of shell plating. It maintains the same interval to prevent trim phenomenon and improve lateral strength. Fourth, it secures space to be used for different purpose. Bulkheads I-VI are installed vertically straight but stern bulkhead is connected with inclination toward stern direction and bulkhead VII is

connected to the bow direction with more inclination. The section between bulkhead I to bulkhead IV has frame to the direction of bow while stiffener structure is located to the stern direction. The frame of bulkhead V-VI is located in the stern direction while stiffener is located in the bow direction. The bulkhead fixing method is to use iron bar on the front and back side.

Shell plating

The shell plating is located between garboard strake and deck and is the body of the ship that composes the final shape. This accounts for the highest share among remaining hull pieces and 176 pieces of 13 starboard and four port sections remain. The shell plating joint method is divided into longitudinal and transverse joint. The longitudinal joint method is based on rabbeted clinker joint¹ while the bow direction has half-lap miter joint². Transverse joint uses tongue and groove joint³ method and half-lap miter joint and the plate is added and fixed by nailing. The way of connecting shell plating is one of the representative characteristics of Sinan Ship.

Pointed stem

Pointed stem is a structure located at the very front of the ship. The shape of the bow is two-layer flat plate structure in the shape of trapezoid close to inverted triangle. At the left and right edge of pointed stem, L-shaped groove was made to be connected to shell plating and inner side was added by plate for reinforcement. The thickness of pointed stem is about 11-12 cm and structural characteristics is to use half-lap miter joint.

Bulwark

Bulwark is located on the upper starboard side of the central of Sinan shipwreck. Bulwark has a clinker joint structure like the joint structure of shell plating. The material made of cedar tree with the thickness of 1.5-2 cm to protect the structure. This is to have sea water inflow and be released through the same circular holes. The upper bulwark has the same circular hole, making it reasonable to interpret it not as the bulwark structure but as structure of shell plating. The reason can be assumed that, as it is lower than waterline comparing to the dead weight and gross weight based, it is far away from the bulwark structure which is side plate of the board.

Bulwark Stay

Bulwark stay is located at the top of shell plating and connected to bulwark (assumed to be the fourteenth-fifteenth stages of the shell plate). This structure plays the role of bulkhead. Three members of this structure were lifted from the starboard side. It is composed of thick wooden plate with 13 cm in thickness and root was connected between structures so each angle was maintained. The bulwark stay is located before and after circular hole located at the center of bulwark. The structure and role as well as interpretation of terms for bulwark stay are required.

Deck

Analysis of bulwark and bulwark stay showed that deck is estimated to be the structure that support fourteenth-fifteenth stages of shell plating. Therefore, it is reasonable to interpret the structure of deck as structure of shell plating inside. In addition, the plate made of cedar tree with the thickness of 1.5-2 cm is added to the top side. The thickness is 10 cm and width 43 cm. There is groove 10 cm wide at the bottom of the outer side area that is connected to the top of the thirteenth stage of the shell plating of bulwark. At the end of the inner side area, scarf joint structure is designed to connect it to the board. As Sinan shipwreck is estimated to be 4.0 m, the shell plating free board is estimated to be 1.5-1.9 m in

¹ Way of joining by making L-shaped groove on the top of the shell plating and groove was made inside the bottom part of the top shell plating.

² Joining two members with the same thickness by digging half of the thickness of the plate and then joining them together (Architecture dictionary)

³ Connection to prevent the timbers from being pushed to the side (architecture dictionary)

height. Then it is known that the deck should be installed at a sufficient height.

Reinforcement

Butt Strap

Butt strap was used to maintain the strength to reinforce the joint area by connecting joint structure to make the length of shell plating member. The method of connection is to put 1-18 iron bars, nine on left and right sides of the joined member respectively. The butt strap has fished joint structure.

Stiffener

Stiffener is a structure that firmly fixes shell plating member attached to the bulkhead to prevent it from being pushed to the outside. Each stage of each section has this stiffener. Stiffener reinforce shell plating and bulkhead has a trapezoidal shape⁴, and the part attached to the bulkhead has a small shape about a quarter of the size of the trapezoid. The fixing method was made strong by driving iron pins.

Bulkhead Frame and Forward Cant Frame

Bulkhead frame is installed on one side of each bulkhead to connect the bulkhead and shell plating firmly. Forward cant frame is located between VII bulkhead and pointed stem. The forward cant frame has twice wider gap compared to I-VII bulkhead. The bigger the space of the section, the weaker the strength of the shell plate so it is assumed that forward cant frame was installed to reinforce shell plating. Bulkhead frame continues from the floor to the deck rostrum and the shape is like stair type according to the shell plating. Iron bar was used for firm fastening.

Scarf-skin

Scarf-skin protects keel, shell plating, bulwark and deck. The thickness is 1.5-2 cm and it is made of cedar and it seems that scarf-skin was added to protect it from harmful insects.

Design

Mast

Mast is located on the front side of IV and VII bulkheads. The structure of the mast is divided into mast, mast leg, mast leg support and cross bar as well as mast leg press (Office of Cultural Properties of Ministry of Culture and Information 1984, 138-139). However, the floor is wider than the floor located at the bottom of bulkhead as it is aligned with the size of the mast and width of the mast leg, a support structure. The role of the floor structure is the basis to pile up the upper structure and support the keel. Moreover, in the report, it is said that floor is the lower structure together with keel and strake (Office of Cultural Properties of Ministry of Culture and Information 1984, 129). However, the mast support at that time played the role of supporting mast leg and that is why it is called mast leg support as it was considered to be part of the mast.

Auxiliary

Liquid tank

Liquid tank is located between IV and V bulkheads and is placed on the left and right shell plating. The shell plating is placed on the front and back direction of the liquid tank support and the bottom plate is placed according to the inclination of the liquid tank support; side plates are placed on four sides. It is watertight to prevent water leakage. In order to erect bottom plate and side plate, the structure same as bulkhead is applied for reinforcement.

⁴ A quadrilateral with two sides (upper and lower) parallel

CONCLUSIONS

The examination on structural characteristics confirmed that the ship has important characteristics from the perspective of the history of shipbuilding technology.

1. It has a V-shaped pointed-bottom hull, which enables the ship to withstand deep water, high and rough waves and swell, wind waves and to perform fast navigation and stability.
2. It secured durability by planning seven bulkheads and eight windows for the space where trade items are piled to secure durability and it has the structure of compartment to store trade items safely.
3. It is equipped with two or more propulsion structures, it has a 'sailboat structure' that can sail against the wind.
4. The front of the ship is equipped with an inverted triangular 'trapezoidal structure' to minimize wave resistance during sailing.
5. It has the water tank structure at the center and left and right of the ship for drinking water supply and balance of the ship.
6. It has the reinforcement structure that has double or triple connection through butt strap, stiffener, frame and cant frame.
7. It has the waterproof and watertight structure to prevent the inflow of water from one compartment to another.
8. The shape is to have a narrow bow and wide stern in order to improve sailing performance.
9. It is equipped with the hull protection structure where a scarf-skin is attached to the outer side of the shell plating, penetrating sea bugs from entering into the hull.

The nine characteristics showed that the ship is equipped with the best shipbuilding technology and structure in Song and Yuan Dynasties of China.

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