EXPERIMENTAL STUDY ON THE EVALUATION OF WORKING A RO-SCULL FOR THE INDONESIAN OUTRIGGER CANOE

インドネシア・アウトリガーカヌーの櫓漕ぎ推進評価に関する実験的研究

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SUMMARY

Capter 1 :

This chapter discussed about the general introduction of these studies which consist of the background and the purpose of these research.

In the South-East Asia countries and Japan located in the northwestern part of the Pacific, there are many rowing fishing boats used for small-scale coastal fisheries. Many of such being boats are made from wood and are decreasing every year due to the material shortage and the aging of ship carpenters besides the deterioration of boats.

Ro-scull is traditional devices in Japan. It is the traditional propeller for small boat using hydrodynamic lift force. It runs the boat very gently and economically. However, the wooden Wasen has almost disappeared. Whereas FRP boats partly inheriting hull form from wooden Wasen are replacing such Wasen. Meanwhile many of rowing fishing boats in subtropical and equatorial zones is dugout canoes or outrigger canoes, which also are decreasing in number and gradually fading away for the same reason.

Indonesia outrigger canoes are propelled mechanically, but many fishermen want to change the propelling method to human power due to rising fuel oil prices. On the other hand, in Japan the small fishing boats are used to be propelled by Ro-Scull.

Based on this reason the author tried to find the potential of applying Ro-Scull of Japanese Wasen to Indonesian outrigger canoe. The author compared the hull form of canoe to the Japanese wasen and examined the possibility of applying Wasen's Ro-scull to outrigger canoe in order to transfer the skill of working Japanese wasen to Indonesian outrigger canoe. Therefore, it was found the enhancement of stability was necessary by mounting a floating structure on the after part of canoe to reduce oscillation in addition to Rogui and Rodoko, a bed to which Rogui was mounted. Rogui is a pivot for Ro-scull and becomes a fulcrum when wasen is propelled by Ro-scull.

Chapter 2 :

This chapter discussed about on statistical analysis of hull type and characteristics of Indonesian outrigger canoe and Japanese Wasen. Indonesia is divided into five major islands, such as Sumatera, Jawa, Kalimantan, Sulawesi and Papua. The research areas are Jawa, North Sulawesi (Manado, Minahasa and Sangihe), Gorontalo province, South Sulawesi (Ujung

Pandang), Molucca and Sulu Island (Philippines). The material consists of the data on 604 Japanese Wasen and 492 Indonesian Canoes (Jawa, South Sulawesi, North Sulawesi and Sulu Island).

The outriggers of Indonesian double-outrigger canoes (Jukungs) are sophisticated in their design because they are constructed with the rudimentary technology. The canoes have distinctive upward-curving outrigger booms, giving a graceful gullwing appearance. The booms are lashed to the hull. The separated connector pieces are attached to the ends of the booms by scarf joint usually with a single wooden peg and lashings. The bamboo floats are attached to the lower ends of these connectors by lashing around the floats. Sometimes, the connector penetrates a hole in the float.

A hull of the Japanese Wasen consists of a keel, two bottom planks, two side plank, a stem post, a transom, frames, and beams. The mid-ship section is very simple because it's consists of six straight lines of a keel, two bottom planks, two side planks and a line between hull top. Accordingly, the hull diagram draws only a few lines of hull top (upper end of side plank), knuckle part between the side and bottom plank and flat keel. Additionally, cross section of the hull at certain ordinates and of a stem post and a transom are given on the design board. The typical flat keel of Wasen consists of the main and stern keels and their boundary showing a line of 'BB'. The stern of keel inclined upward from this location. Generally, the width of the stern keel at its rear end is 60-70% of the keel width at 'BB'. Both sides of the stern keel are slightly curved outward between at the rear.

These are separated into three groups of fishing boats: angling, seiner and gillnet**.** Angling type has the smallest length and width BB/2. The minimum length of all types of boats was around 300 centimeters and BB/2 was assumed to be the width of Wasen was estimated to be about 99 centimeters. On the other hand, a traditional Wasen boat has also 300 centimeters length and 102 centimeters breadth at minimum. This means there is the possibility of applying Ro-Scull to the remaining type of Indonesian canoes.

Chapter 3 :

This chapter deals with stability of outrigger canoe after mounting a floating structure. The statically stability of canoe was examined from the data of inclining test and oscillation test. These tests were conducted under the following condition depending on set outrigger distance: nobody on board (inclining test and oscillation test), one person on board sitting down (inclining test and oscillation test) and one person on board standing up (inclining test only). GM values when the outrigger distance was arbitrarily varied were calculated where is value with one person standing up became around 1.0 meter in the case of 1.3 meters outrigger distance. Then it was found that working a Ro-scull was possible. The hull form was reproduced by ship design software. Where the draft when lightly loaded and nobody onboard was about 14 centimeters, the displacement became about 120 kilograms force (kgf) that was almost equal to the weight at the actual experiment. In the case of the narrowest outrigger distance of 1 meter, GM value became about 1.5 meters. In the same distance, GM value obtained from inclining test was about 1.7 meters. GM value calculated by ship stability software was little smaller than that obtained from inclining test.

In the oscillation test, the boat immediately became still after only one rolling and this means that the N-Coefficient seems to be very big and the result of rolling period in initial 3 times average is about 0.67 seconds. The first about rolling period, average rolling period is ranged between 0.7~1.0 sec. GM value when outrigger distance 1.3 m and nobody on board became about 3.0 m and it is calculated that the rolling period is approximately 0.6 seconds. The second, about N-Coefficient between first rolling motion ($\theta 1$) and second one ($\theta 2$) of the canoe is approximately ten times or more large than usual. This means that the outrigger canoe can damp the rolling motion quickly.

Chapter 4 :

In this chapter the report explains the response of working Ro-scull to Indonesian outrigger canoe. About 30 strokes of each testee sculler's motion of working a Ro-scull were recorded with a digital camera which was set at bow. The recorded motion were analyzed about the movement of six points including head, Rosaki (front edge of Ro-scull arms), right elbow, waist, right knee, and left knee by using of two dimensional video image analyzing software (DippMotion2D V.3.20KP).

In working a Ro-scull, a sculler propels a boat by alternately repeating one motion of pushing a Ro-scull away from the body (pressing) and the other of pulling a Ro-scull to the body (reserving). The veteran was working a Ro-scull in stepping back with the right foot from the centerline and it seemed to be simple and could operate long time, however non veteran were standing with legs open in parallel with centerline and it was difficult to keep balance against canoe's rolling.

Chapter 5 :

This chapter deals with the whole of this study about of working a Ro-scull to the Indonesian outrigger canoe. According to the statistical analysis of hull type and characteristics of Indonesian outrigger canoe and Japanese wasen on this study, Indonesian outrigger canoe is very slim hull with small draft, which means low resistance and propelled with paddle, sometimes sail. Indonesian outrigger canoe has one and double outriggers, that is, they have an outrigger on each side of the canoe. As outriggers moved into more open water, the single outrigger was structurally safer. The outrigger canoes in Sulawesi and Molluca have a hull with two sharp ends.

The typical of outrigger canoe is almost the same with the small fishing boat in Okinawa prefecture locally called Sabani. Sabani in Okinawa, a fishing boat has a unique construction originated from a dugout Sabani (Kuibuni) made from Japanese pine, cedar, deal, oaks or canfer tree. Briefly speaking, the Sabanis in nowadays are semi-dugout or planked boat which have hull shape of old dugout.

In Japan, the traditional boat is known as the Wasen. Japanese Wasen has very slim hull and is operated with Ro-scull. The traditional Japanese boats are characterized by relatively thick planking and few, if any frames. Where frame are not used, hull are strengthened by athwart ship beams are connected to the hull with wedged mortise and tenons. Hull is hard chine with a wide plank keel supporting two garboard planks, with two nearly vertical planks completing the hull. Planking is usually Japanese cedar with cypress often being used for beams, stem and transom. Japanese traditional boats, has almost disappeared. Whereas FRP boats partly inheriting hull form from wooden Wasen are replacing such Wasen.

Based on this study, the author made a comprehensive consideration of the working a Ro-scull experiments to find out the possibility to transfer the Ro-scull of Japanese Wasen and the skills of working to Indonesian canoes. Consequently, it was revealed there was room for further improvements to transfer the Ro-scull and skills of working it to Indonesian outrigger canoe. However, the video footage that recorded the working a Ro-scull motions and was analyzed became an optimum tool to imagine the way of working a Ro-scull when testee scullers who looked a Ro-scull first time to learn working a Ro-scull. In addition, the oscillation test showed a canoe had a characteristic that an oscillation was settled immediately. From this study, it can be recommended that working a Ro-scull for the Indonesian outrigger canoe, like Japanese Wasen, is more suitable when conducted in the calm surface as coastal waters and inland waters including lakes and rivers that are numerous in Indonesia.

CHAPTER 1

GENERAL INTRODUCTION

All through Indonesia, from Sumatera and Philippines to the nearest tip of New Guinea, the Malays and Indonesians have since early times used the double outrigger to stabilize their craft, i.e., a buoyant boom fastened to crossbars on each side of the boat.

The Micronesians and the Melanesians used a single outrigger, that is one side only, and for this reason the Micronesians built their canoes laterally asymmetrical. When the Polynesians adopted the single outrigger on their bilaterally symmetrical canoes they did not follow the Micronesian model but followed that of neighboring Fiji, neither Indonesia nor the Micronesia type of outrigger canoe reached the east Pacific. In Philippine, the Banca is a double outrigger canoe. In short, neither the Indonesian nor the Micronesian type of outrigger canoe reached the East Pacific[1]. Most have inboard engines, although some of the smaller ones still use sail.

In the Southeast Asian countries and Japan located in the northwestern part of the Pacific, there are many rowing fishing boats used for small-scale coastal fisheries. Many of such being boats are made from wood and are decreasing every year due to the material shortage and the aging of ship carpenters besides the deterioration of boats[2-3].

In general, marine activities in Indonesia are supported by small-scale fishing boat in coastal waters. These fishing boats are commonly built up by traditional methods, according to the carpenters' personal ability without any hull lines and with no application of modern techniques of naval architecture.

According to the data analysis of marine and fisheries of Indonesia[4], the National fishing fleet comprised about 788,848 units at the end of 2007, of which 590,314 were marine fishing boats and 198,534 inland open water fishing boats. The development of the number of fisheries facilities during 2002-2007 is shown in Table 1. As this table shows while virtually 50.9 percent fishing fleets were non-powered boat, only 28.3 percent of fishing boats were powered with outboard motor and 20.7 percent with inboard motor.

The indigenous fishing craft in marine fishing are very importance as marine vehicle in the Indonesian fishery activities. Indonesian fishing craft are generally traditional. However, their modernization has been accelerated, especially on the motorization, since the declaration of the Economic Exclusive Zone within 200 miles of Indonesia waters.

The recent trend on the motorization of the fishing boats is steady and remarkable, especially in highly developed areas of marine fisheries, i.e. the eastern coast of Sumatera facing straits of Malacca, the northern coast along the Jawa Sea and South Sulawesi and its surrounding areas.

In Japan, the traditional boat is known as the Wasen. The traditional Japanese boats are characterized by relatively thick planking and few, if any frames. Where frame are not used, hull are strengthened by athwart ship beams are connected to the hull with wedged mortise and tenons. Hull is hard chine with a wide plank keel supporting two garboard planks, with two nearly vertical planks completing the hull. Planking is usually Japanese cedar with cypress often being used for beams, stem and transom[5)].

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Indonesian outrigger canoes are propelled mechanically, but many fishermen want to change propelling method to human power due to rising fuel oil prices. On the other hand, in Japan the small fishing boats are used to be propelled by Ro-Scull. Based on this reason the author tried to find the potential of applying Ro-Scull of Japanese Wasen to Indonesian outrigger canoe. The author compared the hull form of canoe to the Japanese Wasen and examined the possibility of applying Wasen's Ro-scull to outrigger canoe in order to transfer the skill of driving Japanese Wasen to Indonesian outrigger canoe. Therefore, it was found the enhancement of stability was necessary by mounting a floating structure on the after part of canoe to reduce oscillation in addition to Rogui and Rodoko, a bed to which Rogui was mounted. Rogui is a pivot for Ro-scull and becomes a fulcrum when a Wasen is propelled by Ro-scull.

This thesis is consisting of five chapters. Each chapter has introduction, methodology, result and discussion, conclusion and the total paper is finally followed by published material (references).

In chapter 2, 3 and 4, the research was conducted in several selected areas of Indonesia Nagasaki prefecture, and Omura Bay, respectively. Chapter 1 discussed about general introduction of this thesis, namely the background and the purpose of this study. Chapter 2 discussed about on statistical analysis of hull type and characteristics of Indonesian outrigger canoe and Japanese Wasen. In this chapter, the author describes the characteristics of the hull construction on outrigger canoe compared to Japanese Wasen and possibility of applying Ro-scull to the remaining type of Indonesian canoe. Chapter 3 discussed about stability of outrigger canoe after mounting a floating structure in the inclining test and oscillation test. In this chapter, the author explains the mounting of Rodoko and the reproduction of hull form and the displacement calculating by ship design software. In addition, the stability using by Maxsurf and Hydromax analysis module is explained. Chapter 4 deals with the response by working the Ro-scull to Indonesian outrigger canoe. In this chapter, the report explains of working a Ro-scull by three testee sculler on outrigger canoe. Finally, chapter 5 is general conclusion of all independent chapters.

Table 1 Number of Fishery Facilities by Type of Facilities, 2002 - 2007 4)

Type of Facilities	Year						Increasing Average (%)	
	2002	2003	2004	2005	2006	2007	2002-2007	2006-2007
Number of Fishing Vessels	**594 968**	**702 234**	**729 682**	**753981**	**783 684**	**788 848**	**5.97**	**0.67**
Marine Capture	460 298	528 717	549 100	555 581	590 317	590 314	5.23	0
Non Powered Boat	219 097	250 469	256 830	244 471	249 955	241 889	2.21	-3.23
Outboard Motor	130 184	158 411	165 337	165 314	185 983	185 509	7.66	-0.25
Inboard Motor	111 034	119 837	126 933	145 796	154 379	162 916	8.03	5.53
Inland Openwater Capture	**134 670**	**173 517**	**180 582**	**198 400**	**193 308**	**198 534**	**8.58**	**2.7**
Non Powered Boat	120 522	154 907	145 529	172 322	163 735	159 781	6.7	-2.41
Outboard Motor	11 768	17 677	33 599	23 844	27 212	37 747	32.82	38.71
Inboard Motor	2 380	933	1 454	2 234	2 361	1 006	-0.6	-57.39

CHAPTER 2

ON STATISTICAL ANALYSIS OF HULL TYPE AND CHARACTERISTICS OF INDONESIAN OUTRIGGER CANOE AND JAPANESE WASEN[6)]

2.1 Introduction

In the Southeast Asian countries including Indonesia as well as in Japan, there are many small fishing wooden boats. The canoes in the Southeast Asia islands generally used on smooth sea in inland waters have relatively long outrigger floats directly fixed to their frameworks of rigid structure. On the other hand, canoes in tropical islands in the Pacific waters where sea condition are often heavy have a short and big wooden outrigger indirectly fixed to the outrigger framework of flexible structure composed of thin logs assembled at short intervals in longitudinal length.

The former outrigger system are design to overcome waves with their rigid structure while the latter outrigger system are design to absorb torsion moments produced by a phase difference of quarter waves between the hull and outrigger with their flexible structure. The slim hull of the outrigger canoe has generally pointed both ends and their mid-ship section represent a smooth line like that a modern steel boat.

According to the data analysis of marine and fisheries[4)], about 44.8 percent of the fishing boats were concentrated in middle and east Indonesia region; the remainder were accounted by Jawa, Maluku, Sulawesi and Kalimantan. Fishing boats are used in fishing inland open water are classified as follows: (i) non powered boats, such as: outrigger canoe/dugout boats, plank built boats, small size (the largest boat used is less 7 m in length), medium size (the largest boat used is between 7 to 10 m in length) and large size (the largest boat used is 10 and more in length); (ii) Outboard powered boats; (iii) inboard powered boats.

Many reports on Indonesian canoe have been published by several researchers such as:

B. R. Finney[7)] published voyaging canoes and the settlement of Polynesia in 1977 and B. Fagan[8)] published an Outrigger to the outback in 1990.

Christian Nooteboom[9)] published an extensive account of Indonesian canoes in Dutch in 1933. James Hornell[10)] published his observation on Indonesia canoes in 1920 and A. C. Haddon[11)] published a summary of museum models and description of Indonesia canoes from the available literature in 1920. The summarized reports[12-13] of these two researchers based on detailed fieldwork of Oceania canoes, have proved to be recently in 1938.

Souchi Nakano[14] published his detailed observation of Sumatera fisheries including fishing boats in 1943. A restricted report of Admiralty in 1944 contains an account based on pre-war condition of the fishing and trading craft and the fisheries of the Philippine islands[15].

C. A. Gibson-Hill[16] reported his observation of Singapore fishing boats in 1950. He also reported on Malay fishing boats[17] and T. W. Burdon and M. L. Parry[18] published their observation on Malay fishing methods in 1954.

A. Horridge[19-22] published many reports and books on Indonesian craft trough his field observation since 1978.

Edwin Doran[23] published his historical consideration on distribution of several sailing Pacific canoes in 1981.

E. R. Alfred[24] listed indigenous craft in Singapore according to the types of the craft in 1987.

Hisayoshi Tadano[25-26] presented his naval architecture report on wooden ships in Southeast Asia in 1986.

Horridge, G. Adrian[27] published his outrigger canoes of Bali and Madura, Indonesia in 1987.

Gary Dierking[28] published his building outrigger sailing canoes in 2007.

Nick Schade[29] published his building ship-planked boats in 2009.

The outrigger canoes of Indonesia typically have double outriggers, that is, they have an outrigger on each side of the canoe. As outriggers moved into more open water, the single outrigger was structurally safer. By comparison, the double outrigger stands a good chance of suspending the main hull from the outriggers in heavy seas. In Indonesia, those fishing boats are propelled mechanically. Meanwhile the impact of fuel oil price increase in the world has influenced fishermen operating small fishing boats in coastal area. Therefore many fishermen consider to changes the propelling method to human power because they want to decrease fuel oil consumption.

On the other hand, in Japan, the small scale fishing had been operated by using boats with a Ro-Scull. However, such fishing boats have almost disappeared today.

This chapter of outrigger canoes in North Sulawesi is an extension of the above reports in order to develop the small-scale fishing boats in Indonesia, especially at North Sulawesi. The canoes in North Sulawesi have a very slim hull with an outrigger on both sides. They commonly belong of some types: Londe, Pelang, Cadik and Jukung in the local names. The former is rowing or sailing canoes[30].

2.2 Indonesian canoe's characteristic

Indonesian marine fishing activities commonly are supported by small-scale fishing boats, and about 95% of which are operated in coastal waters. From the percentage, probably more than 90% marine fishing is supported by the fishing boats of less than 10 grots tonnages. Most of these outriggers were made of round bamboo[3].

The outriggers of Indonesian double-outrigger canoes (Jukungs) are sophisticated in their design because they are constructed with the rudimentary technology. The canoes have distinctive upward-curving outrigger booms, giving a graceful gullwing appearance. The booms are lashed to the hull. The separated connector pieces are attached to the ends of the booms by scarf joint usually with a single wooden peg and lashings. The bamboo floats are attached to the lower ends of these connectors by lashing around the floats. Sometimes, the connector penetrates a hole in the float.

Canoes of Lea-Lea of Ujung Pandang have single outrigger and an outrigger float bamboo is fixed by nylon lines onto the free ends of two transverse booms of wood. Canoes in Sulawesi generally have two outrigger floats and 2-3 booms to hold them.

An Indonesian outrigger canoe has very slim hull with small draft, which means low resistance, and is propelled by paddle, sometimes by sail. There is no "rogui" or a pivot for Ro-scull. Figure 2-1 shows an Indonesian outrigger canoe with sail[3] and Fig. 2-2 shows an Indonesian outrigger canoe without sail.

2.2.1 Manado dugout canoe without a "snout"

The double outrigger dugout canoes with the so called snout were mostly found along the Manado beach and in Lembeh. The canoes with the snout are called "londe" while those without are called "pelang". The size of the snout of the stern is 23 to 74 cm long, 3 cm anterior diameter and 8 cm base diameter, and the snout has the shape of an elephant tusk. The snout is made two parts. The base part extends up to the length of the hull and is a continuous part of the keel while the anterior section is nailed to the free and of the base. The stern snout which is relatively smaller than the bow snout is a remnant of full size snout. The 84% of measured sample had stern snout of less than 10 cm long. The length of the bow snout is not in correlation with the length overall and the age of the canoe. It is significantly correlated to the width and depth of the canoe[3)].

A snout is also seen in a fishing craft near Ranong (between Thailand and Burma) which used for pearl gathering. The snout size is about 30-50 cm long for both ends and has a wider diameter than those of Manado. Unlike the Manado snout, the snout of these crafts is formed as a continuous part of the hull without any additional section. In additional planking on the hull, the shorter hull is caused by the formation of a snout at stern end. This construction shows the hull distinctly from the additional planking.

The Manado snout seems to be mainly for decoration purpose. The fishing crafts in this area are mainly used for angling, vertical line, long line, squid jigging, bonito trolling, gill net and others including spearing around reef area. On the practical side, the snout causes some inconvenience when fishing and may cause some fishing line trouble during operation. The fishermen of Batu Lubang Village of Lembeh who originated from the Sangihe Island in the northern waters of Sulawesi, brought with them the know-how to build their own dugout canoe to the native of the island. When building a new canoe, the owner fisherman selects the best performing canoe in the village and uses this as the model. The principal dimension of the model canoe is taken as that of the new canoe. For the detailed hull shape, a galvanize wire is used to measure the section of the model canoe and to match this with those of the new canoe. This procedure allows the fine adjustment on the hull lines. The fishing craft in this area are mainly used for angling, vertical line, long line, squid jigging, bonito trolling, gill net and others including spearing around reef area.

The maintenance of the craft is done locally. To protect the craft from shipworm, the hull is regularly heated by using a torch made of coconut fronds. Repair of the dugout canoe is usually done after around 10 years use by cutting the worn-out hull top and replacing this part with a new planking. This maintenance work may have given the fisherman the idea of increasing the free board by adding a plank to the simple dugout. It can therefore be said that this may be the origin of the development of the semi-dugout.

2.2.2 Single outrigger canoe in Ujung Pandang

The semi-dugouts type at Ujung Pandang/Makassar called Lepa-lepa or Sopek, are mostly with single outrigger and a quarter rudder. For the hull material, according to the senior fisherman of the village, the mango tree of Borneo cut after harvesting the fruits is the best quality material. It is believed that a good fruit bearing tree as a hull material will bring abundant fish catch. The L/B, length/width ratio, of the small semi-dugout is comparatively smaller than that of Manado canoe and is a fair type hull. This probable reason for such hull type is the use of the single outrigger and the motorization of the craft. However, as compared to the modern seagoing fishing boat, this type of crafts is slimmer. The sail of the canoes in Ujung Pandang and Manado is made of thin polyethylene film supplied as agriculture use. Judging on the material used, the resistance of the craft must be extremely small in sailing condition.

The smaller craft are used in angling, gill net, long line for catching fish, coral and mackerel and squid jigging.

2.2.3 Kendari dugout canoe

Along the way to the island, “katamaran” type fishing craft for lift net, “Bagan Perahu”, fishing and a number of bamboo fish corals, “Sero” were sighted. The outside of Kendari Bay about 5 nautical miles eastward is the coral line island of Bokori surrounded by vast coral, rock and sand which are as making the island good for fishing. Majority of coastal fishing crafts around Sulawesi are with outriggers. However, all the craft in Kendari have no outrigger. The crafts are used for angling (52%), gill netting (30%), bamboo fish corals (13%), bamboo fish pots (5%), long line and other fishing activities such as spearing, seaweed and seashell gathering. The maintenance of the craft is done locally. To protect the craft from ship worm, the hull is regularly heated using a torch made of coconut fronds. Repair of the dugout canoe is usually done after around 10 years use by cutting the worn-out hull top and replacing this part with new planking. The craft is propelled only by a traditional sail of tilted square. This old type of craft may be influenced by Arab-Indian craft design.

The process of construction is similar to that of the Japan style fishing boat. The process of construction is that first the keel with the sternpost and transom are laid, followed by the attachment of the hull planking, and finally the setting of the frames and beams. The frames are made from naturally shaped tree branches fitted to the shape of hull.

The fishing craft of Sulawesi are generally smaller in length than those of the Philippines. Comparing the dugout crafts, the Manado craft with double outriggers are slimmer than those of the Kendari craft without outrigger. Even with single outrigger, the craft Ujung Pandang well resemble in hull shape to those of Kendari without outrigger[31)].

2.3 Japanese Wasen

In the Japanese-style fishing boat, a slim hull and refined profile was thought as a base of boat's design, because the reduction of running resistance was very important in the old days when the Wasen was propelled by man and wind power. The hull types and the constructions of fishing boat vary due to supply condition of wood materials and the quantity of forest resources available by area. In traditional Wasen boat building technique, shipwrights first usually draw a hull diagram of a boat on a wood plank, then the boat is built by referring to the design board. Japanese Wasen is used to be propelled by Ro-Scull. Figure 2-3 Japanese wasen with 'Ro'[32)] and Fig. 2-4 Using by Ro-scull.

A hull of the Wasen consists of a keel, two bottom planks, two side plank, a stem post, a transom, frames, and beams. The mid-ship section is very simple because it's consists of six straight lines of a keel, two bottom planks, two side planks and a line between hull top.

Accordingly, the hull diagram draws only a few lines of hull top (upper end of side plank), knuckle part between the side and bottom plank and flat keel. Additionally, cross section of the hull at two certain ordinates and of a stem post and a transom are given on the design board. The typical flat keel of Wasen consists of the main and stern keels and their boundary shows a line of 'BB'. The stern of keel inclined upward from this location. Generally, the width of the stern keel at its rear end is 60-70% of the keel width at 'BB'. Both sides of the stern keel are slightly curved outward between at the rear[5)].

The hull diagrams of Wasen are often abridged to a plain view diagram or cross section. For such imperfect diagrams, the lacking parts should be made after referring to the many data of other Wasens that are built around the same time for the same kind of use.

In Okinawa, a dugout boat of the old type "Subuni" changed to the Sabani of "Itoman-hagi", a semi-dugout boat, which applied planks on the dugout bottom. "Nan yoyogi" is a type of the Sabani which replaced the dugout bottom to thick keel planks. The Sabani of traditional fishing boats in Okinawa changed like this because of supply conditions of hull materials[3)].

With the ongoing motorization of indigenous fishing crafts of Java, Sulawesi and Philippines, similar changes in Japan are expected also to happen in the development of the coastal fishing craft of Japan in Southeast Asian countries. As a reference, the wooden fishing craft of Japan underground changes due to motorization. Motorization fishing craft in Japan started during the Taisho Era (1912-1926).

2.4 Methodology

2.4.1 Location surveyed and materials

Indonesia is divided into five major islands, such as Sumatera, Jawa, Kalimantan, Sulawesi and Papua. The research areas are Jawa, North Sulawesi (Manado, Minahasa and Sangihe), Gorontalo Province, South Sulawesi (Ujung Pandang), Molucca and Sulu Island are shown in Fig. 2-5 Map of Indonesia. The material consists of the data on 604 Japanese Wasen and 492 Indonesian Canoes (Jawa, South Sulawesi, North Sulawesi and Sulu Island) shown in Fig. 2-6 Location of research area.

The outrigger frame generally consists of two booms of bamboo attached to a bamboo float, although these canoes are different in their shapes and construction by area or site. In Indonesia, double outriggers canoe with long outrigger floats of bamboo on both sides are dominant and single outrigger canoe with an outrigger on one side are found rarely.

2.4.2 Measurement of dimension of outrigger canoe

In general, the canoe in the Indian Ocean has slim hulls and shorter outriggers compared to those in the Java Sea. The dimensions consists of length over all (Loa), maximum breadth (B), depth a midship (D), length of an outrigger float (Lf), width from one float to the other float on the opposite site (BB), interval between the fore and aft booms holding the floats (Intv), the height of an outrigger amidship above keel (Hor), height of stem and stern tips (Hs, Hn), height of dugout base (Hdo) and snout of the Londes (El) as shown in Fig.2-7 [3)]

The principle dimensions of Loa, B and D were taken in external size and the full load draft, d is determined from the height of outrigger float amidship, because the canoe can load until a certain draft when the outrigger is half submerged in the water. Various sizes of the outrigger frameworks are taken as an equivalent diameter or size, if the outrigger float has a complex shape or manufactured from multiple materials.

2.4.3 Measurement of hull-lines

Hull-lines of typical canoes taken were draw with a pantograph specially made for the measurement of typical types of canoe sites. This pantograph is very convenient for enabling direct tracing of the hull-lines in a scale factor of 1/4 as shown in Fig. 2-8 Measuring method of hull-lines by means pantograph.

Cross sectional curve measurement of the canoe's hull lines was made with the pantograph using the same procedures as Gunawan and Shibata[2)].

The line trace is made on following procedures:

(1) The easel with a drawing board is placed on the hull side at a certain location marked with chalk and then the board is adjusted exactly so as to be perpendicular against the longitudinal center line of the hull.

(2) One end of the pantograph is set onto the board and a pencil is also set onto the intermediate corner of the pantograph.

(3) The other end of the pantograph is moved slowly along the hull surface from the center of keel to bulwark top. Thus the pencil moves along the paper drawing a cross sectional line.

(4) The breadth of keel, Bk, and the breadth between bulwark tops, Bi, are also measured and recorded beside the line at the location.

(5) Finally, hull-lines based on the lines obtained by the pantograph are drawn in the laboratory.

2.4.4 Analysis of the data

The calculation of statistical outrigger canoe condition and dimensional data as mentioned above were made by means of the computer with Microsoft Excel program in the laboratory and cluster and regression analysis.

2.5 Results and discussions

2.5.1 Comparison of principal particulars between Indonesian outriggers and Wasen boats

The outrigger canoes in Sulawesi and Molluca have a hull with two sharp ends. The local varieties in hull-lines and outrigger framework are seen by fishing village. There are four types of canoes in North Sulawesi: Londe, Pelang, Pelang motor and Pambut in the local name. These are separated into three groups of fishing boats: angling, seiner and gillnet**.** Figure 2-9 shows the relationship between length and BB/2 by three types. Based on the result, angling type has the smallest length and width BB/2. The minimum length of all types of boats was about 300 cm and BB/2 was estimated to be about 99 cm. On the other hand, Fig.2-10 shows the relationship between length and Breadth of Japanese Wasen. From this result, angling type has the smallest length and breadth, and the size of length was about 300 cm and breadth was about 102 cm. It is suggested that the minimum breadth of Japanese Wasen and BB/2 of Indonesian outrigger canoe are almost the same size. This means there is the possibility of applying Ro-Scull to the remaining type of Indonesian canoes.

Figure 2-11 shows the relationship between length and BB/2 of angling type boat. From the seven research location, Ujung Pandang boats have almost the same length and variable range BB/2. Sulu Island boats have the longer length and BB/2. It is because that Sulu Island is located near open sea and so their boats have the bigger length and breadth. Meanwhile Ujung Pandang is located in coastal area, so the boats have the smaller length and breadth.

2.5.2 Comparison of main dimension between each location and fishing type of Indonesian outriggers

Based on the location, Fig. 2-12 and Fig. 2-13 shows that the average plus/minus Standard deviation (SD) of length over all (Loa) and width (BB/2) in comparison among some locations of angling boats. Numbers in these figures mean the total data number by each location. Sulu Island is the biggest and Ujung Pandang is the smallest in angling type boat. Figure 2-13 show the almost the same average size, while Ujung Pandang is smaller than other location in angling type.

Figure 2-14 and Fig. 2-15 show the average plus/minus standard deviation (SD) of length over all (Loa) and width (BB/2) in comparison among some location of gill net boats. Both of the average and standard deviation of length over all of Minahasa are the smallest and the average Loa of Sangihe is the biggest. On the other hand, width (BB/2) average of Jawa is the biggest.

2.5.3 Potential of mounting the Ro-scull of Japanese Wasen to Indonesian canoe

From the studies, it appears that a half of the distance between two outriggers (BB/2) corresponds approximately to the breadth of Wasen. There is a possibility that the stability of canoe is temporarily assured, though not permanently. The next step is to mount the Ro-Scull of Wasen to outrigger canoe. The canoes have no such part as corresponding to the Rodoko, a bed to which a Rogui or pivot for Ro-Scull is mounted. Rogui becomes a fulcrum when a Wasen is propelled by the Ro-Scull in Fig. 2-16[32)]. If a Ro-Scull is going to be mounted to a canoe, such part as Rodoko has to be installed or added to the hull. Even though a Rodoko and Rogui could be mounted to an outrigger canoe, a question that remains is whether the smooth propelling by Ro-Scull is available for the canoe just like Wasen. If these problems could be solved, it is believed that outrigger canoes can be propelled by working a Ro-Scull.

2.6 Conclusions

Indonesian outrigger frame of Indonesia canoe generally consists of two bamboo booms attached to a bamboo float. The booms lie across the hull in enough intervals of length. The framework and shape of the outrigger are respectively different by village or area. These local variations arose because the canoes have developed so as to fit the sea condition, especially to the characteristics of sea waves in each operation. The canoes that are generally used in smooth sea and inland waters have relatively long outrigger floats directly fixed to their frameworks of rigid structure. An Indonesian outrigger canoe has very slim hull with small draft, which means low resistance, and is propelled by paddle, sometimes by sail. There is no “Rogui” or a pivot for Ro-scull.

In general, those fishing boats are propelled mechanically. Meanwhile the impact of fuel oil price increase in the world has influenced fishermen to operate small fishing boats in coastal area. Therefore many fishermen consider to changes the propelling method to human power because they want to decrease fuel oil consumption. On the other hand, in Japan, the small scale fishing had been operated by using boats with a Ro-Scull. However, such fishing boats have almost disappeared today.

These are separated into three groups of fishing boats: angling, seiner and gillnet**.** Angling type has the smallest length and width BB/2. The minimum length among all types of boats was about 300 cm and BB/2 was estimated to be about 99 cm. On the other hand, a traditional Wasen boat has also 300 cm length and 102 centimeters breadth at minimum. It is suggested that the minimum breadth of Japanese Wasen and the width (BB/2) of Indonesian outrigger canoes are almost the same size. This means there is the possibility of applying Ro-Scull to the remaining type of Indonesian canoes. There is a possibility that the stability of canoe is temporarily assured, though not permanently.

Fig. 2-1. Indonesian Outrigger canoe with sail[3)]

Fig. 2-2 Indonesian Outrigger canoe without sail

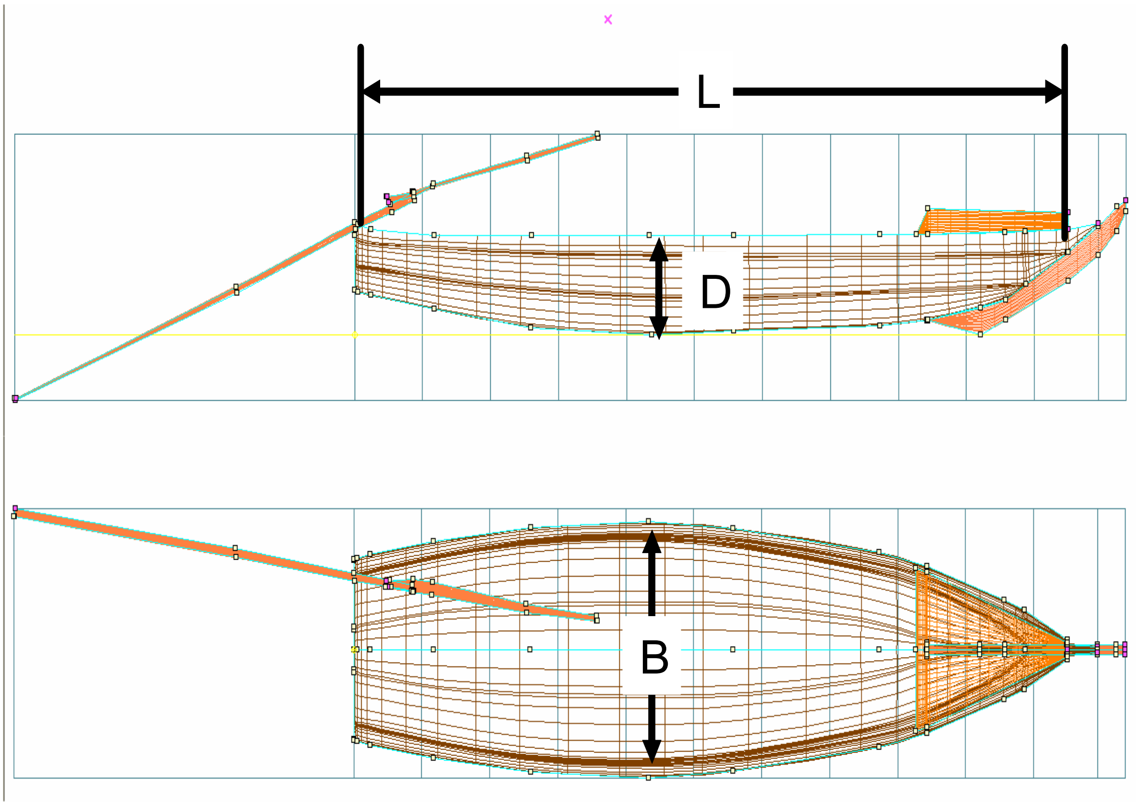

Fig. 2-3 Japanese Wasen with Ro-scull[33)]

Fig. 2-4 Using by Ro-scull

Fig. 2-5 Map of Indonesia

Fig. 2-6 Location of research area

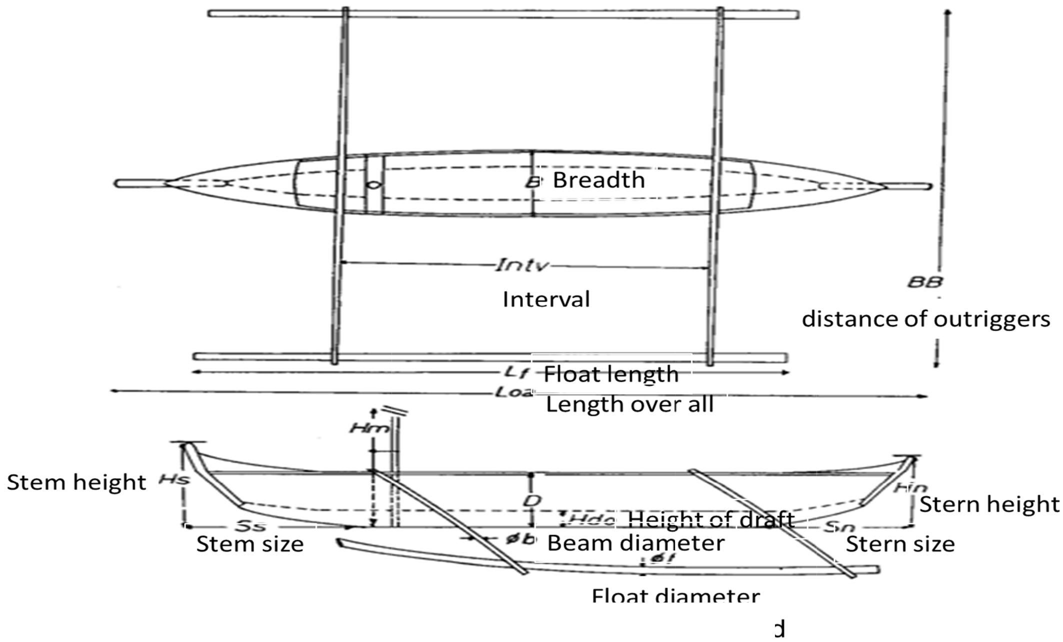

Fig. 2-7. Dimension of an Outrigger canoe[3)]

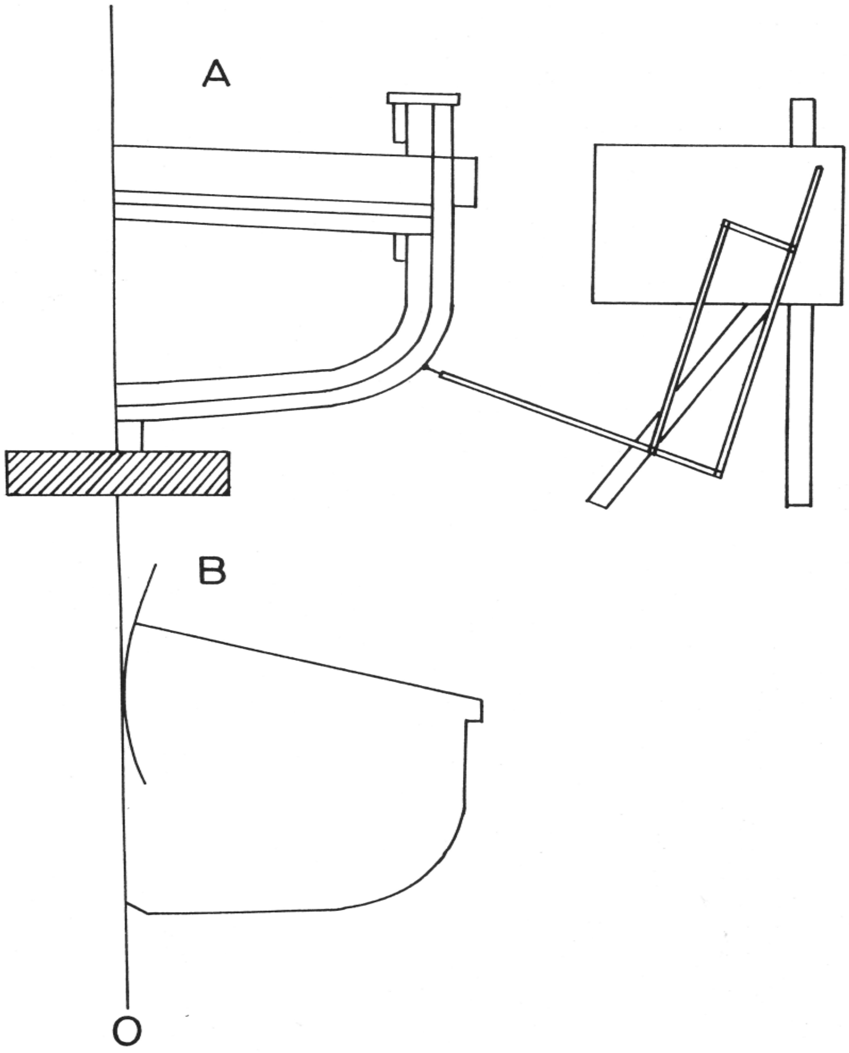

Fig. 2-8 Measuring method of hull-lines by means pantograph[3).

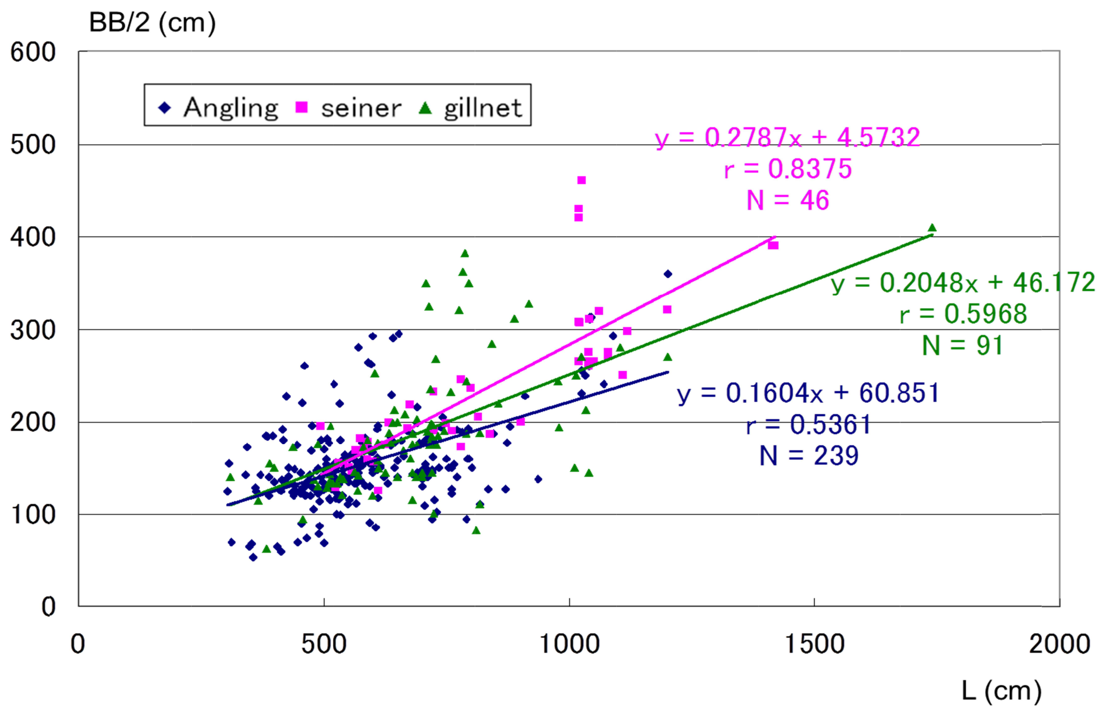

Fig. 2-9 Length and width (BB/2) of Indonesian outrigger canoe (three fishing types)

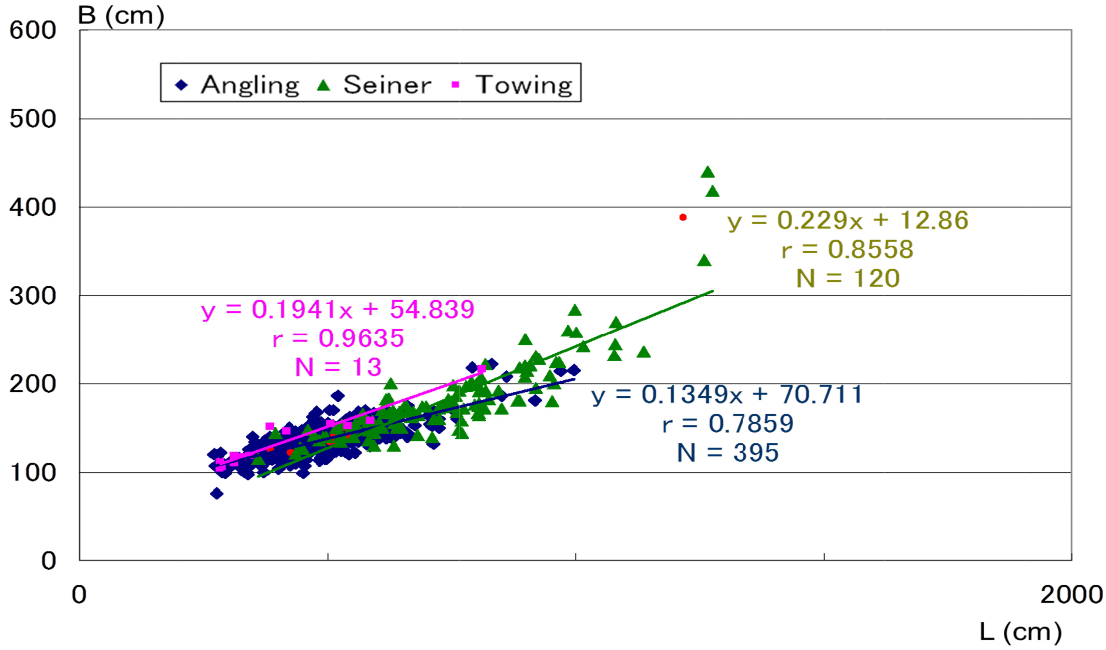

Fig. 2-10 Length and Breadth of Japanese Wasen (three fishing types)

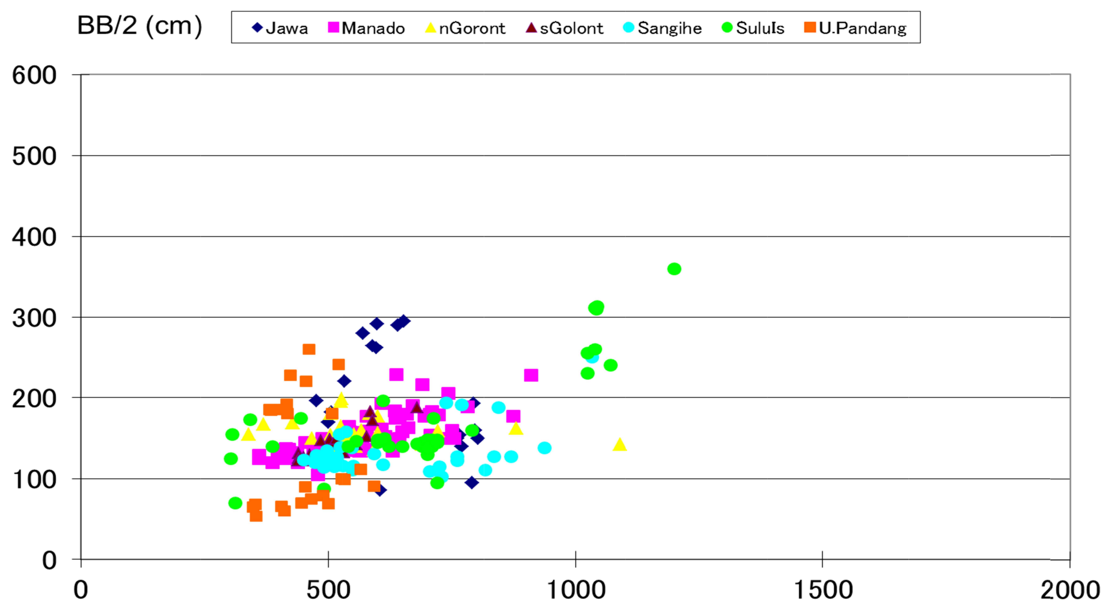

Fig. 2-11 Length and Width (BB/2) of Indonesian Outrigger Canoe
(Angling boat of 7 fishing village)

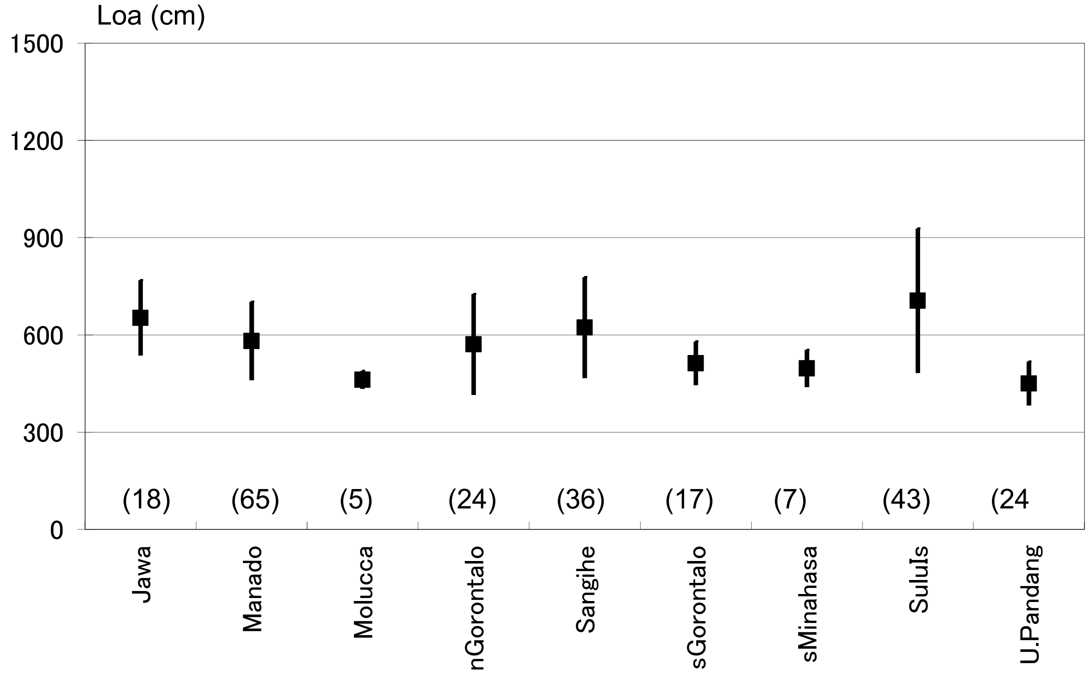

Fig. 2-12 Average plus/minus SD of Loa angling boats (comparison by location)

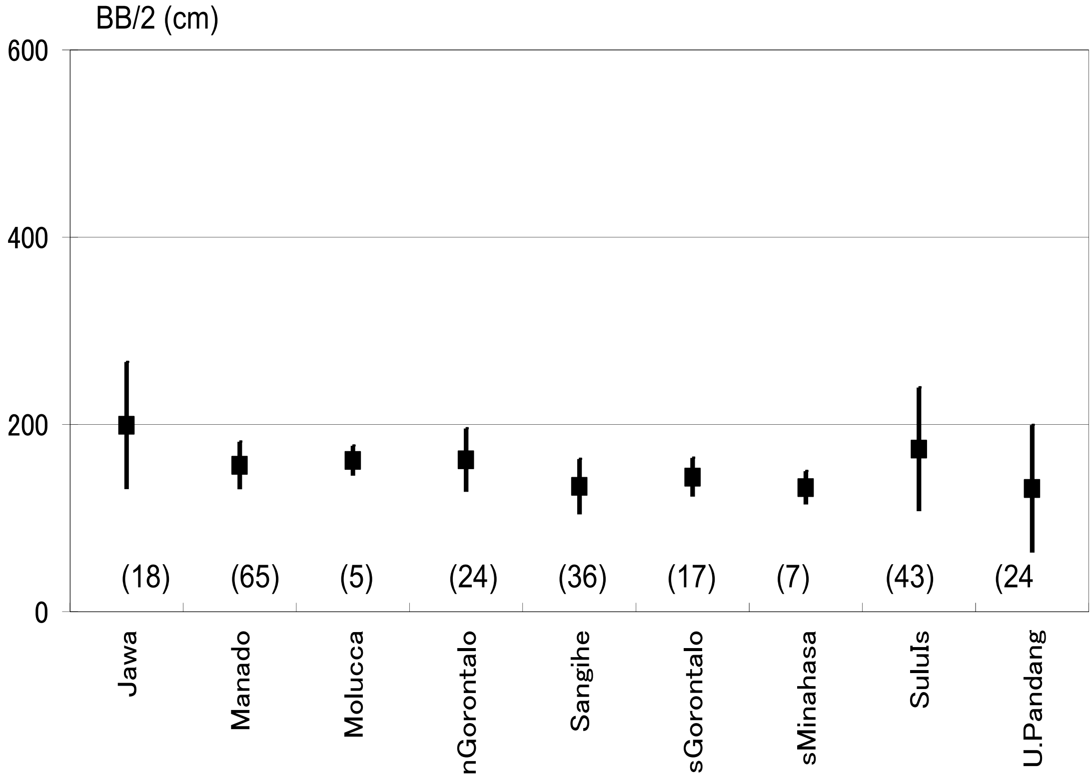

Fig. 2-13 Average plus/minus of BB/2 of angling boats (comparison by location)

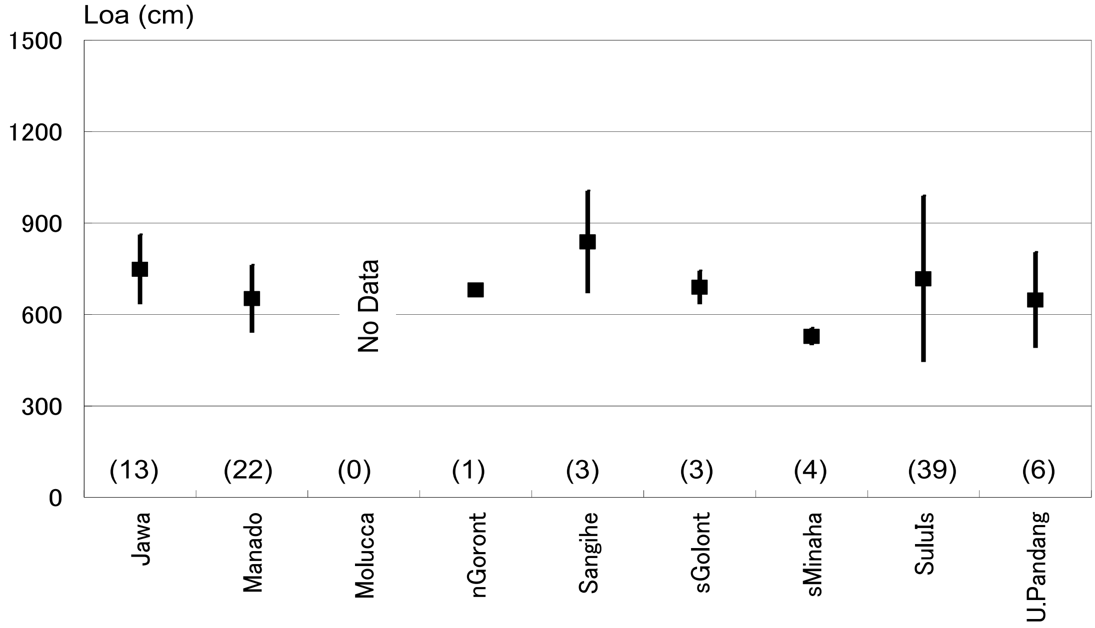

Fig. 2-14 Average plus/minus SD of Loa of gill net boats (comparison by location)

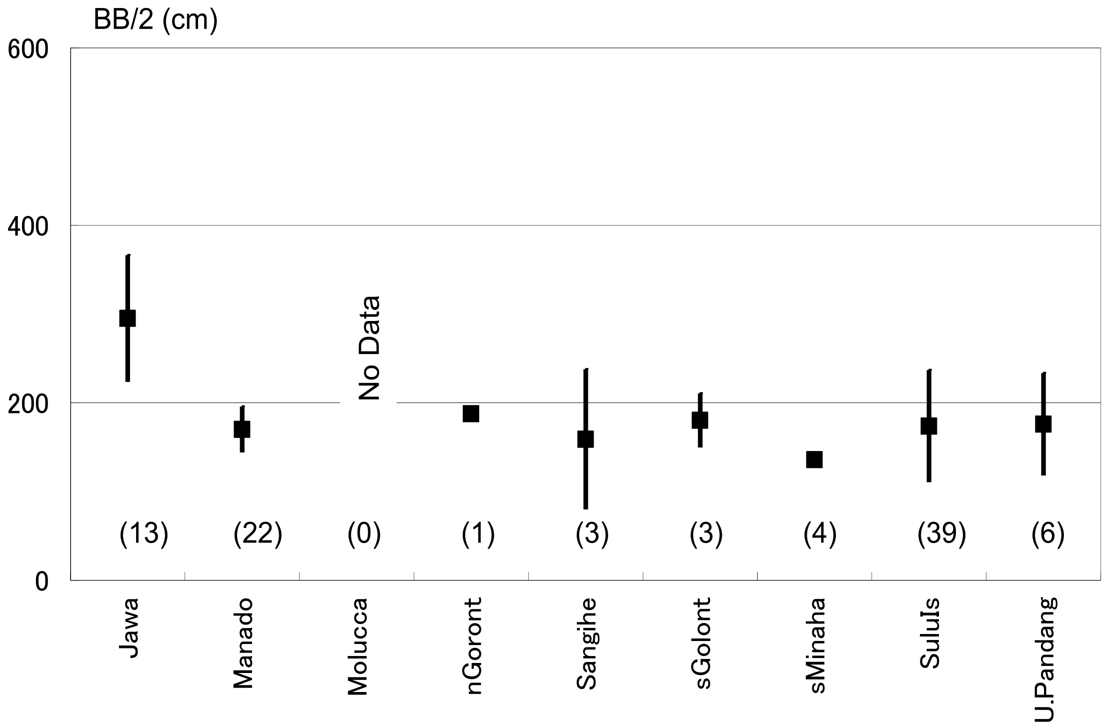

Fig. 2-15 Average plus/minus SD of BB/2 of gill net boats (comparison by location)

Fig. 2-16 View to mount the "Rogui" at the "Rodoko" to the Wasen boat[32)]

CHAPTER 3

STABILITY OF OUTRIGGER CANOE AFTER MOUNTING A FLOATING STRUCTURE[34)]

3.1 Introduction

Stability is defined as resistance to change deterioration or displacement and it is synonym to reliability and dependently. In naval terms, it means the ability of a watercraft to maintain equilibrium or resume its original upright position after displaced by the sea wave or strong winds.

The key component of any watercraft or canoe is the stability. Put simply, a watercraft with poor stability will capsize easily. If the craft is made of heavier-than-water materials then it relies on the displacement of water to achieve buoyancy. In such a situation, capsizing leads to it sinking.

At its most basic level, an outrigger consists of some sort of a float, attached via one or more booms to the gunwales (top edge) of a boat. While modern outriggers can be made from a variety of sturdy buoyant materials, the outrigger float has traditionally been some piece of light wood, and the boat type most often associated with is a dugout canoe. However outriggers also found on plank built boats, although the necessity is lessened for the boats. Builders of plank boats have more ability to improve roll stability by changing the hull shape than makers of dugout canoes. The action of an outrigger is twofold. First, it adds buoyancy to the boat, since outriggers are made of floating materials irrespective of their shapes. More importantly, the addition of a float at the end of the boom dramatically increases the roll stability of the small canoes to which outriggers are typically attached.

An outrigger canoe is a type of boat that features a main hull in the form of a canoe and an outrigger that extends from the main hull to increase stability. An outrigger features arms with a float attached at the end. The float can vary in size and is usually much smaller than the main hull, though an outrigger canoe can feature a float that is just as long and wide as the main hull. Some versions of this craft feature more than one outrigger, and crafts that feature just one outrigger usually have the outrigger structure on the port, or left, side.

The extra stability provided by the outrigger on an outrigger canoe allows the craft to be operated in choppy or unsteady waters, and it makes traveling at higher speeds much easier. Canoes fitted with a sail are more likely to feature an outrigger than canoes without sails that are generally operated on flat, calm water. For even more stability, an outrigger canoe may feature a second hull that is the same size and structure as the main hull. The two hulls work as outriggers for each other; this style is sometimes known as a catamaran and it is ideal for faster speed in the open water.

3.1.1 Boat stability

The center of gravity is the point in the boat where all of the forces of gravity (down) are equal. In other words, if it could balance the boat in a certain point, this would be the point where it balances. The center of buoyancy is the point where all the forces upward from the water are acting. It is essentially the center of the underwater volume of the boat.

Stability is determined by the relationship between three things, center of gravity (CG), center of buoyancy (CB), and something called metacentric height (GM). 'G' represents the boat's center of gravity, the point through which the downward forces due to the boat's entire structure and contents can be said to act. 'B' is the center of buoyancy, the point of trough which the upward forces (bestowed by buoyancy) can be said to act. By contrast B's position is anything but fixed. The shape of a hull's immersed volume altered drastically with shifts in heel and trim. Buoyancy acts on all the underwater parts of the hull. The total of this buoyant upward force can be represented as acting through one point, the center of buoyancy (B). The total weight of the boat, including all the stores, fuel, the equipment and fishing gear, can be represented as acting through one point, the center of gravity (G) [35].

The distance between G and M is known as the metacentric height (GM) and at small angle of heel, is proportional to the boat's stability. If GM positive, that's to say M is above G, the boat is stable. If it is negative, the boat will heel until stability is restored to the condition known somewhat charmingly as the angle of roll. The time G and B were in vertical alignment and the hull was in a state of transverse equilibrium, i.e. zero heel. B moves to leeward of G creating a couple, basically a lever or righting arm, usually known as GZ, whose purpose is to force the boat back upright again.

When wind or a wave rolls the boat over, the center of buoyancy moves to one side and levers the boat back upright. This horizontal distance, between the forces at G and B, is called the 'righting lever' (or GZ). If the boat rolls too far, the center of buoyancy can't move over any more and the boat becomes overly top heavy and capsized. This tendency to the capsizing happens much sooner if the center of gravity is moved higher. As a boat rolls, the shape of its hull limits how far the center of buoyancy can move. The beam of the boat's hull and the height of the deck edge above the water determine how much buoyant force is available and how large the righting lever can be. Normally, when the edge of the deck rolls below of water, the angle of roll with the largest possible righting lever has passed. If the boat gets lower in the water, from loading too much weight or catch, the freeboard (the distance from the water to the deck edge) is reduced. In this condition, when the boat rolls, the deck edge goes underwater sooner and reduces the righting lever more quickly. The effect is to reduce the range of stability safety (meaning the boat capsizes sooner at a smaller angle of roll).

3.2 Methodology

3.2.1 Location and materials

The canoe used for the working a Ro-Scull experiment was a monohull type one where is Length over all (Loa) = 3.62 m, Breadth (B) = 0.43 m and Depth (D) = 0.27 m with weight 45.0 kgf, as shown in Fig. 3-1 State of refined canoe.

The experiment was conducted on the calm water of coastal area of Omura Bay in Nagasaki Prefecture where there was no wind and tide disturbance. The weight of portable weights used for the inclining test was 10 kgf.

3.2.2 Modified of outrigger canoe

As explained in Chapter 2, based on analysis of hull form data of 604 Wasens and 492 Indonesian outriggers, it was suggested the possibility of applying Wasen's Ro-scull to the Indonesian outrigger canoe of remaining type.

However, to work a Ro-scull of canoe with staying standing up it was necessary, in addition to the aforementioned hull form comparison, to mount a Rodoko on which a Rogui a fixed point (fulcrum) of Ro-scull, was mounted and to solve the problem of hull stability to match the rise of gravity associated with the standing position. Therefore, the partial refurbishment of the after part of canoe and the optimization of outrigger distance (BB) were considered. More specifically, these were: (1) the mounting of Rodoko and Hayao, a rope connecting Ro-scull with hull; (2) the mounting of a floating structure on the after part of canoe for more reserve buoyancy and reduced oscillation; and (3) the assessment of outrigger distance for more stability. A Rodoko was newly mounted on the after part of canoe. In particular, as for the abovementioned (2) and (3), the necessary knowledge for the propulsion by working a Ro-scull was obtained through the examination of stability depending on the form of floating structure and the outrigger distance.

When mounting a floating structure on the part of canoe, Okinawa's Sabani hull[36)] form referred to. Also, a Rodoko and outrigger arms were bolted on the canoe for removal. In particular, the outrigger distance was adjustable in five stages (1.0m to 1.7m). The statically stability when the outrigger distance was arbitrarily varied was examined by inclining test and oscillation test. Thus, the outrigger distance that made working a Ro-scull able was examined.

3.2.3 Reproduction of hull form and displacement calculation by ship design software

Maxsurf is a powerful three dimensional surface modeling system allowing for systematic experimentation and rapid optimization of hull lines, appendages, decks and superstructures. With a customized interface, the various software modules use a wide variety of modeling aids and fairing tools, Maxsurf can generate hull forms to high degrees of complexity, including curves and dynamically trimmed surfaces[37)].

Maxsurf provides naval architects with software tools for all phases of the boat design and analysis process. By using a common 3D surface model, design files can be optimized to accurately flow through concept, initials, and detailed design stages. With Maxsurf, users can confidently model hull forms; assess stability and strength; predict performance; and carry out initial structural definition and analysis.

The hull form was measured by a pantograph. By using ship design software (Maxsurf), the hull form was reproduced and the displacement is calculated.

3.2.4 Inclining test and oscillation test

3.2.4.1 Inclining test

Inclining test and oscillation test were carried out to estimate stability by each condition. The data was recorded to PC at sampling frequency 20Hz via from the motion detection sensor SB2G, which is made by SEIKA, Co. Ltd, with A-D converter.

The outrigger was set up to a both side of canoe, it could be applied as a Trimaran model of a boat because these outrigger played a role as the buoyancy body. Therefore, at this time the GM value was calculated by the following formula as a model of the single hull type from the inclination angle of the inclining test[38)].

$$\tan\theta = \frac{w \times l}{W \times GM}$$

whereas: w = Weight (kgf), l : Moving distance of weight (m)

W= Total weight (kgf), θ : Inclining angle

The inclining test and oscillation test were conducted under the following condition depending on set outrigger distance:

(1) Nobody on board (inclining test and oscillation test)

(2) One person on board sitting down (inclining test and oscillation test)

(3) One person on board standing up (inclining test only)

The static stability of canoe was examined from the data of inclining test and oscillation test. Although the test canoe was an outrigger one, the author regarded it to be a standard dugout canoe and performed inclining test.

3.2.4.2 Oscillation test

The rolling period test is a frequently used method to determine the stability of smaller boats. Rolling period test can be performed at any time and can perform it themselves. GM can be determined approximately by means of a rolling period test. It is performed by measuring the rolling period of the boat. Stiff boats have a high GM value and a short rolling period; while boats with a low GM value with a long rolling period.

The test can be performed in the following way, mooring lines should be slack and the boat should not be too near the harbor. The boat is made to roll. When the boat's roll is sufficient (approximately 2 deg. – 6 deg. to each side) the boat is allowed to roll freely and naturally. The time is taken which it takes the boat to go approximately four complete oscillations. One complete oscillation will have been made when the boat has moved right across to the other extreme side (i.e. starboard) and returned to the original starting point. The time in seconds (T) for one oscillation is found by dividing the number of oscillations made with the total time. If the calculated value of T, in seconds, is less than the breath of the boat (B), in meters, it is likely that the initial stability is sufficient, provided that the boat carries full supplies and fishing gear and has high freeboard.

As the boat's supplies decreases (T) becomes longer since the boat's (G) becomes higher and GM becomes larger. In such circumstances it is recommended that the calculated value of (T), in seconds, should not be more than 1.2 times of (B).

Calculating of the rolling period[39)]:

$$T = \frac{f\,B}{\sqrt{GM}} \quad ; \quad GM = \frac{(0.8\,B)^2}{T^2}$$

In this formula:

B = the maximum beam of boat

T = the average rolling period

f =0.4

The following conditions are to be met as far as practicable at the moment of inclining test (general conditions of the ship):

(1) Weather conditions are to be favorable.

(2) The ship or canoe is to be moored in a quiet, sheltered area free from extraneous forces such as to allow unrestricted heeling. The ship is to be positioned in order to minimize the effects of possible wind, stream and tide.

(3) The ship or canoe is to be transversely upright and the trim is to be taken not more than 1% of the length between perpendiculars. Otherwise, hydrostatic data and sounding able are be available for the actual trim.

(4) The ship or canoe are capable of including oscillations are to be secure.

3.3 Results and discussions

3.3.1 Hull form refinement

Maxsurf is able to facilitate the design of a hull using developable surface. The test canoe was refined as shown in Fig. 3-1. Once a design has been modeled using Maxsurf, its stability and strength characteristics can be assessed using the Hydromax analysis module. Hydromax provides the Maxsurf user with a range of powerful analysis capabilities to handle all types of sustainability and a strength calculation. Figure 3-2 shows the drawing in which the hull form was reproduced by ship design software before refinement, and Fig. 3-3 shows the drawing in which the hull form was reproduced by ship design software after refinement and after refinement with a Ro, show in Fig. 3-4.

3.3.2 Examination on stability and optimal outrigger distance by inclining test

The outrigger distance was arbitrarily varied, and the optimal outrigger distance was examined by inclining test and oscillation test. Figure 3-5 shows the placement of equipment in inclining test. Table 2 shows the weight of each equipment. Figure 3-6 Show an example of wave forms obtained in the actual inclining test. Based on these results, GM values when the outrigger distance was arbitrarily varied were calculated and shown in Fig. 3-7. According to this figure GM value with one person standing up became around 1.0 meter in the case of 1.3 meters outrigger distance. Then it was found that working a Ro-scull was possible.

The hull form was reproduced by ship design software. Figure 3-8 shows the calculated displacement of reproduced hull form. Where the draft when lightly loaded and nobody onboard was about 14 centimeters, the displacement became about 120 kilograms force (kgf) that was almost equal to the weight at the actual experiment.

Meanwhile, when outriggers were mounted, GM values calculated by ship stability software were shown in Fig. 3-9. In the case of the narrowest outrigger distance of 1 meter, GM value became about 1.5 meters. In the same distance, GM value obtained from inclining test was about 1.7 meters. GM value calculated by ship stability software was little smaller than that obtained from inclining test.

3.3.3 Result of oscillation test

Figure 3-10 shows one of example of wave forms in oscillation test (nobody onboard and outrigger distance are1.3m). Based on this figure, the boat immediately become calm by only one rolling and this means that the N-Coefficient seems to be very big and the result of rolling period in initial 3 times average is about 0.67 seconds. On the other hand, Table 3 shows the average rolling period between 3 rolling motion and the calculated result of N-Coefficient between the first rolling motion (θ_1) and the second one (θ_2) by each condition.

The first about rolling period, average rolling period is ranged between 0.7~1.0 sec. For example, from the Fig. 3-7, GM value when outrigger distance 1.3 m and nobody on board became about 3.0 m and by using formula (B) it is calculated that the rolling period is approximately 0.6 seconds. Compared with Fig. 3-10 in actual the rolling period in initial 3 times average is 0.67 seconds, and this means that the both of the rolling period from Fig. 3-9 seem to be almost same. The second, about N-Coefficient between first rolling motion (θ_1) and second one (θ_2) of the canoe is approximately ten times or more large than usual of ship[39] as shown in Table 3. This means that the outrigger canoe can damp the rolling motion quickly.

3.4 Conclusions

This research intended to transfer the skill of working a Ro-scull of Wasen to the canoe hull form, that is why the authors refined the hull form of test canoe so that working a Ro-scull became able in a canoe. Figure 3-11 shows the state of working a Ro-scull in outrigger canoe. As a result of this study, the following points became apparent:

(1) It is difficult to work a Ro-scull standing up in the dugout canoe because of too small GM value and poor stability.

(2) When boarding the canoe, it is believed that there is a margin load carrying the weight to maintain the outrigger inclination. When a person boarded the canoe and worked a Ro-scull, in the case of outrigger distance of 1.3 meters, GM value became about 1 meter and the stability increased.

(3) The hull form was reproduced by ship design software and the drawings were obtained. A calculation was made by using such drawings. In consequence, although the displacement was almost equal to the actual measurement value, GM was underestimated a little bit.

The breadth of canoe is narrower than that of wasen. Therefore, the motion at working a Ro-scull is limited because of insufficient foot space. As future tasks to realize working a Ro-scull in the canoe, the improvement such as preparing more foot space will be needed.

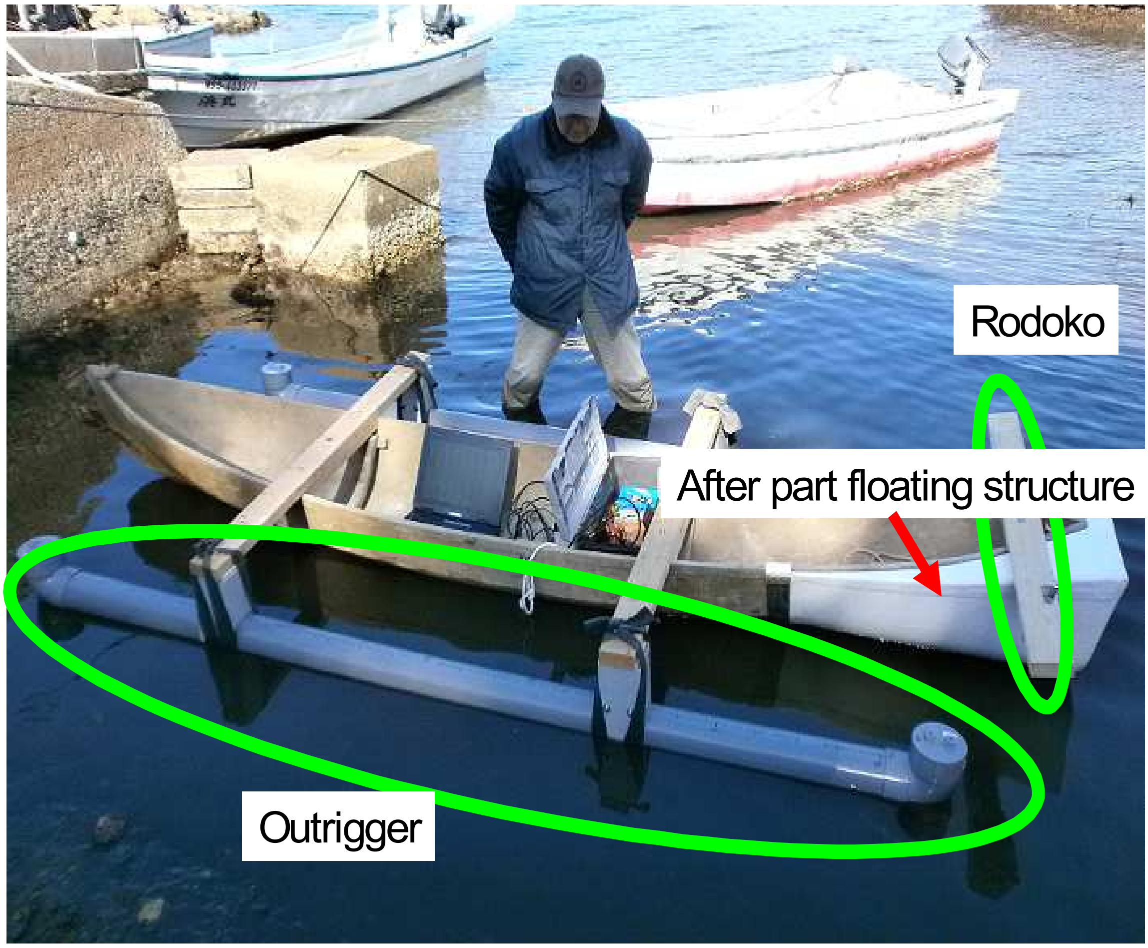

Fig. 3-1 State of refined canoe

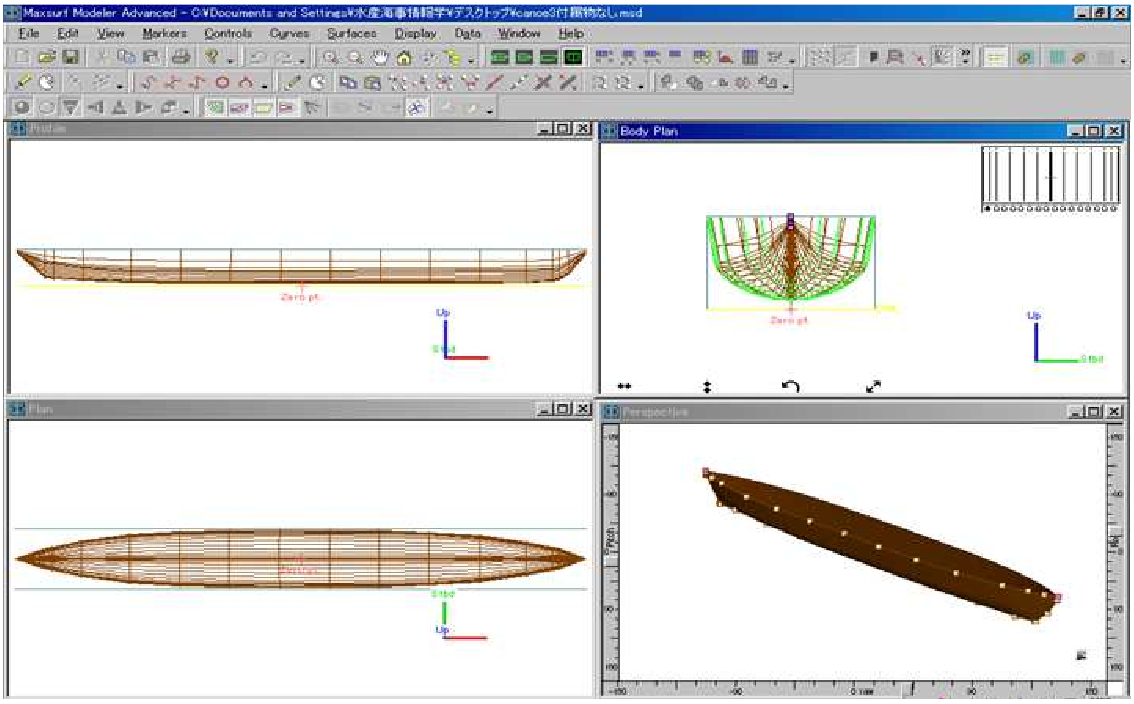

Fig. 3-2 Reproduction by Maxsurf ship design software

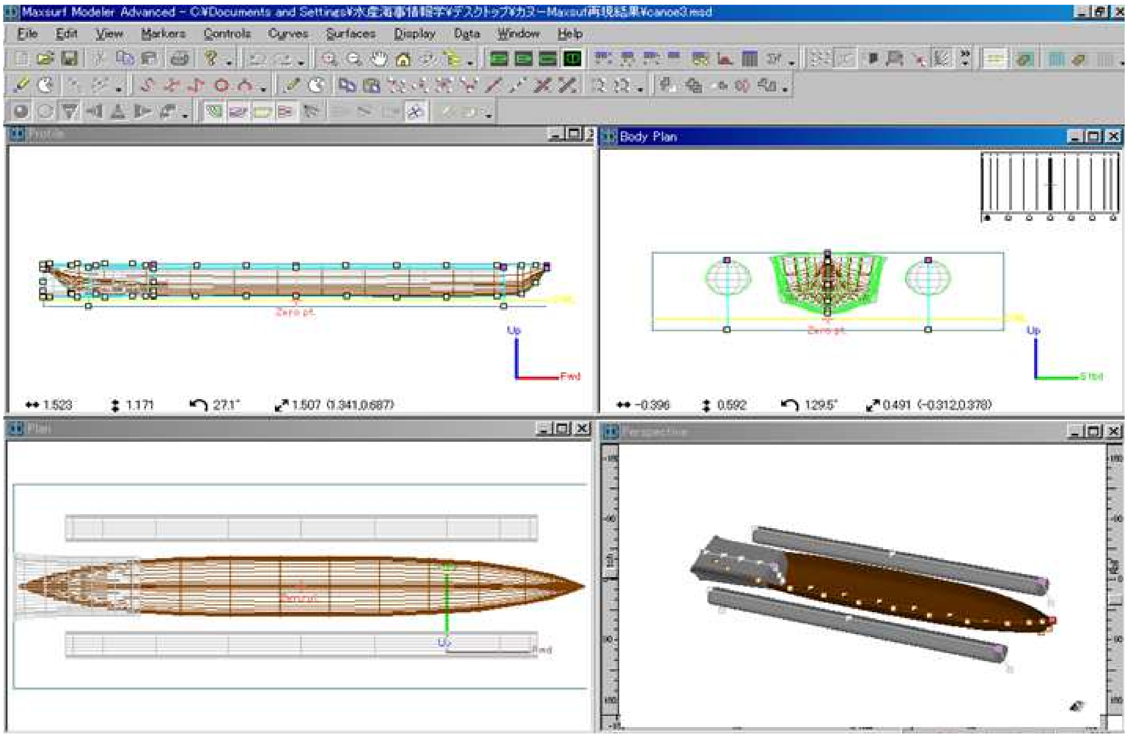

Fig. 3-3 Reproduction by Maxsurf ship design software (after refinement)

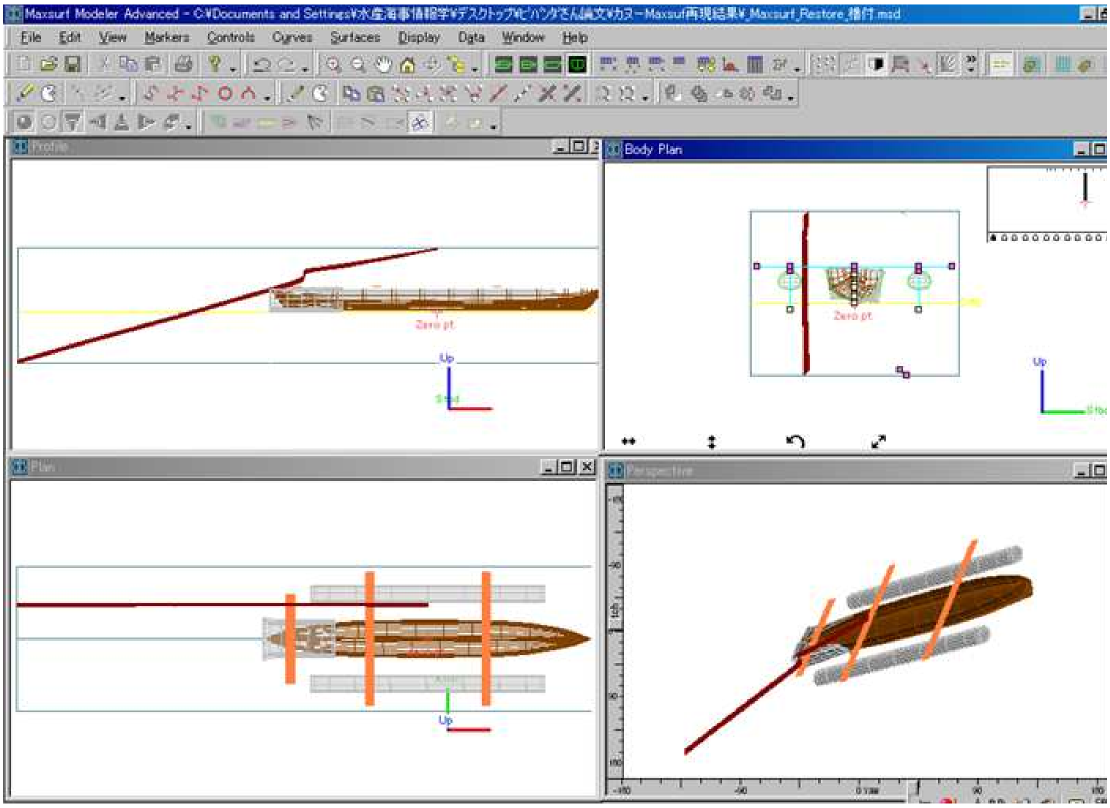

Fig. 3-4 Reproduction by Maxsurf ship design software (after refinement with a ‘Ro’)

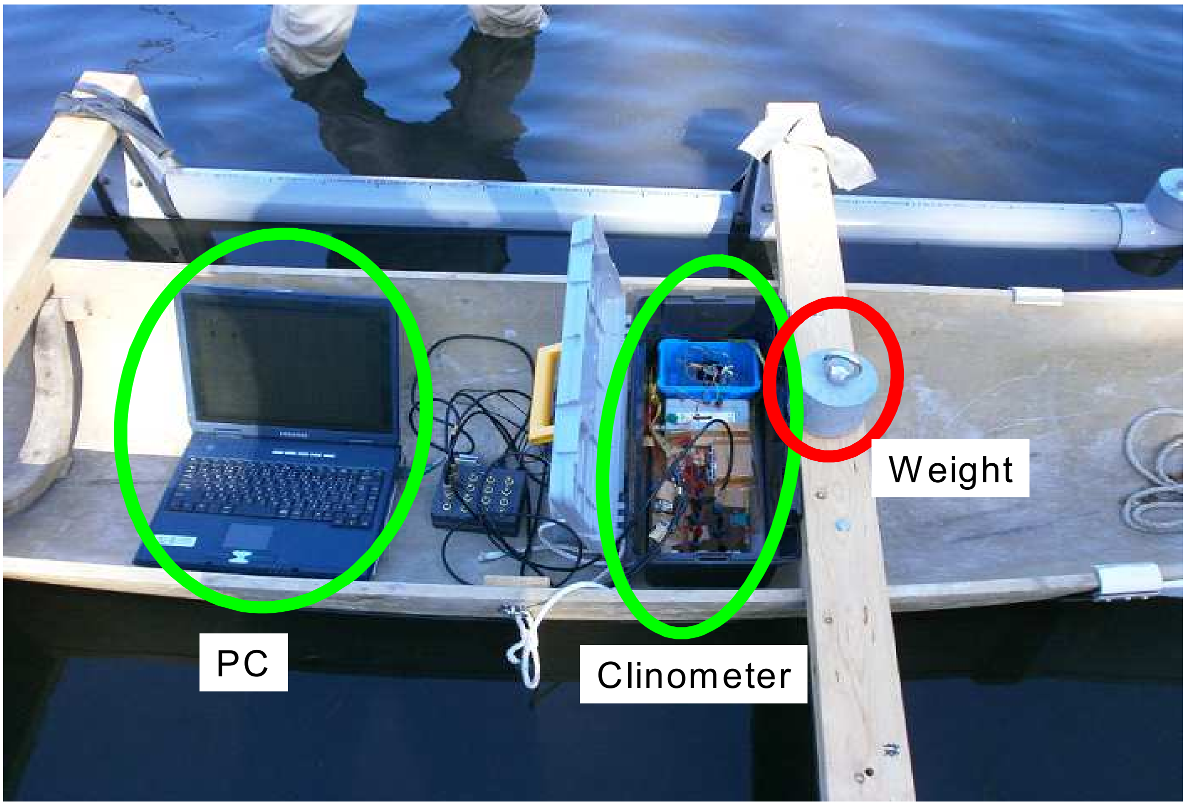

Fig. 3-5 State of the placement of equipment in Inclining test

Table 2. Weight of each test equipment

Specific weight of onboard equipments (Unit: kgf)

	Condition		No-one onboard	No-one onboard	One person onboard
1	Empty canoe weight		45	45	45
2	Outrigger arms One arm's weight is 5.3 kgf (5.3kgf×2)		10.6	10.6	10.6
3	Rodoko		2.1	2.1	2.1
4	Floating structure		6.1	6.1	6.1
5	Fixing rubber band		1.2	1.2	1.2
6	Outriggers One outrigger's weight is 6.7 kilograms (6.7kgf×2)		13.4	13.4	13.4
7	Measuring instruments		21.7	26.5	26.5
	Breakdown	Weight	5.2	10	10
		Battery	8.2	8.2	8.2
		Sensor	4.1	4.1	4.1
		PC	4.2	4.2	4.2
8	Person onboard				56.8
	Total weight (kgf)		100.1	104.9	161.7

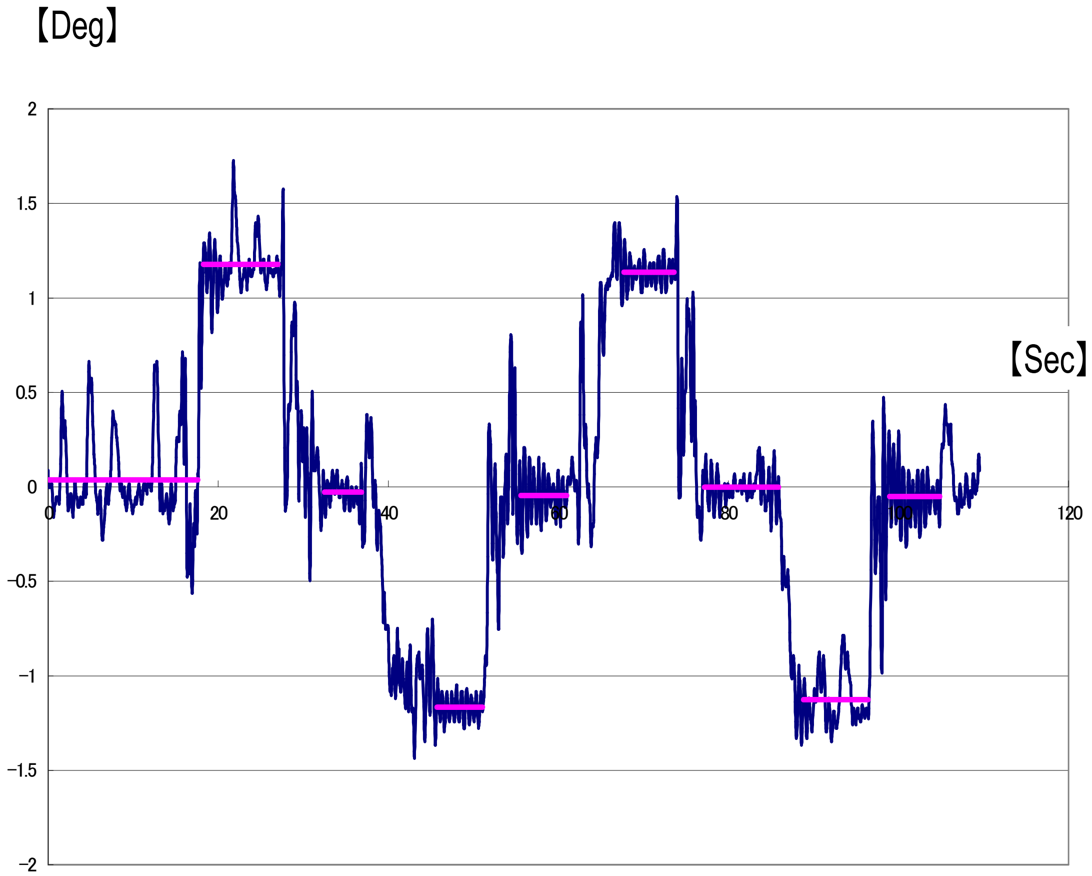

Fig. 3-6 Example of wave form in Inclining test

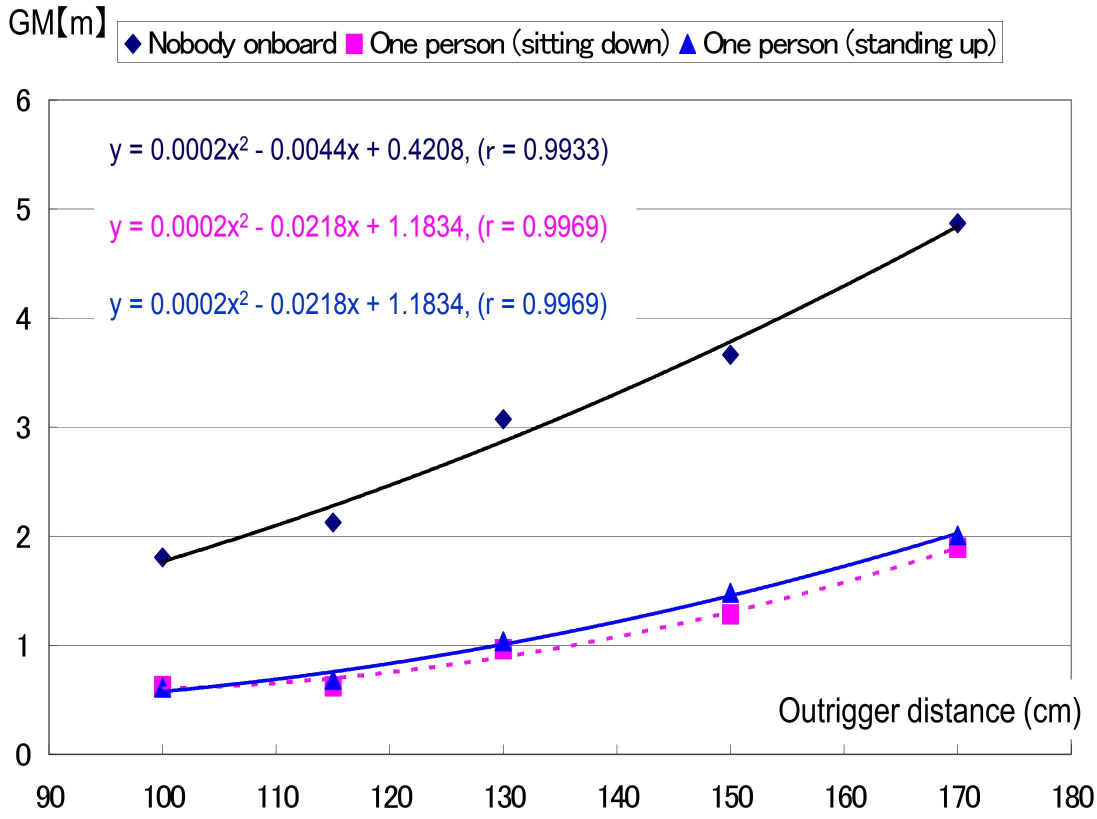

Fig. 3-7 Relationship between Outrigger distance and GM obtained by Inclining test

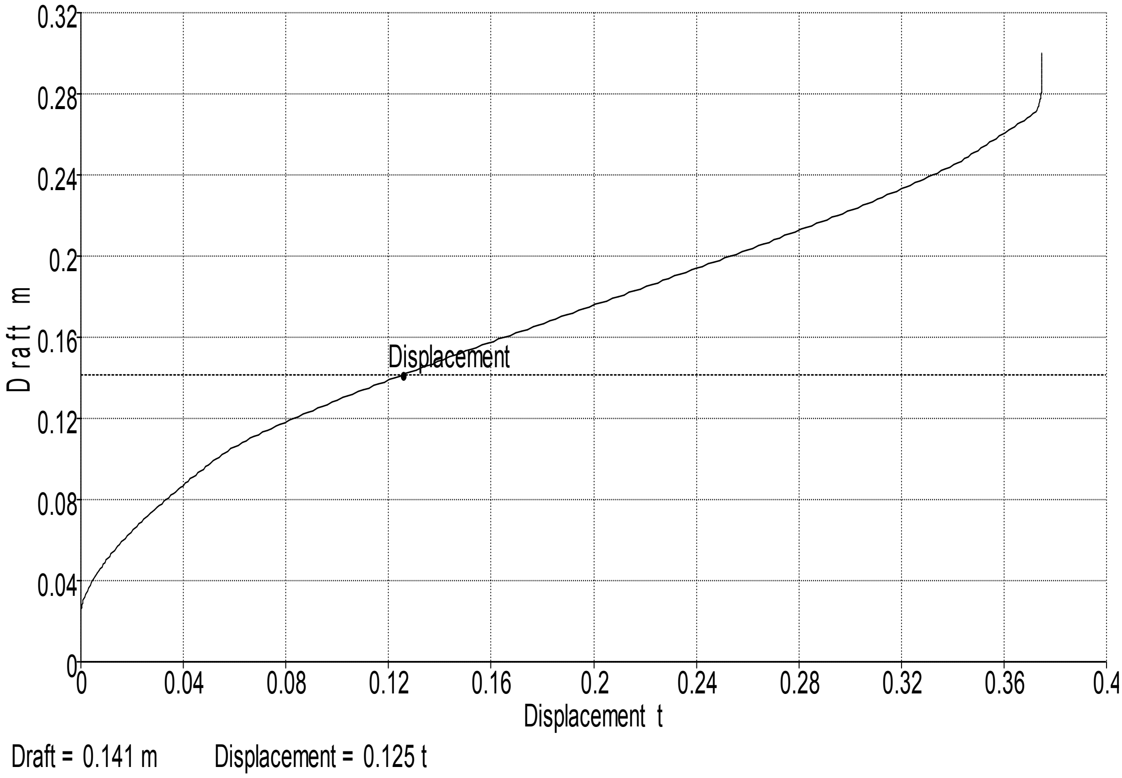

Fig. 3-8 Displacement curves of test canoe by Hydromax ship stability software

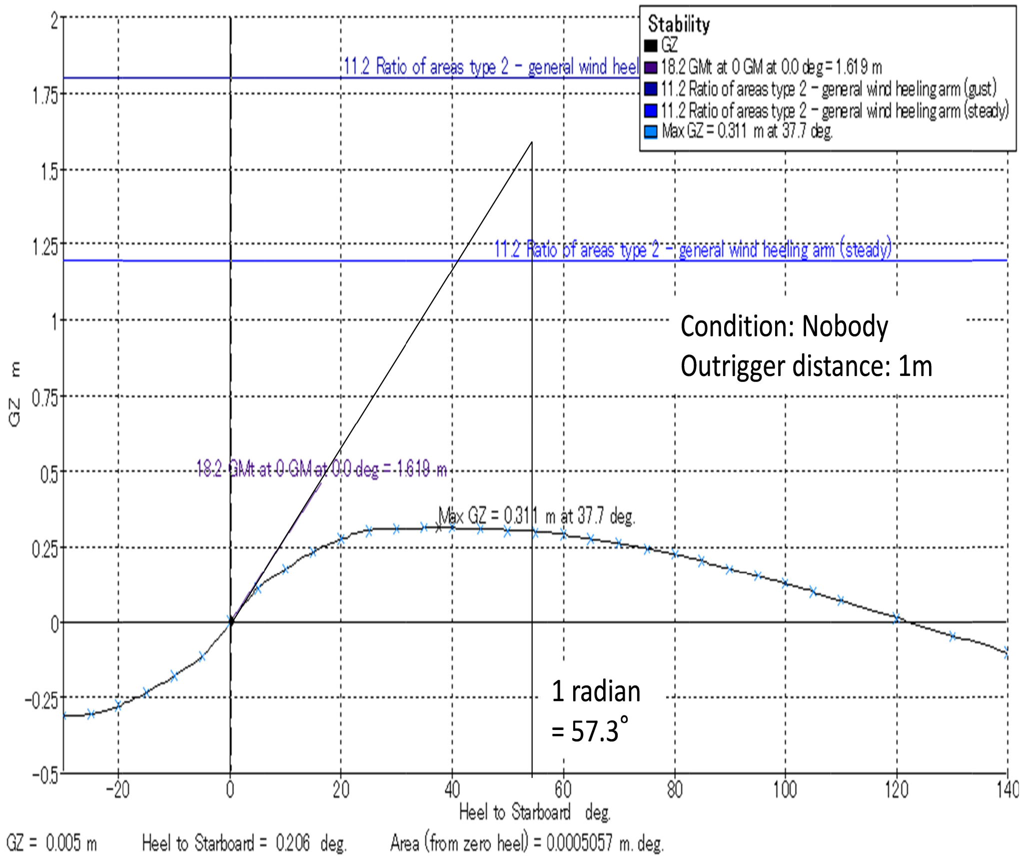

Fig. 3-9 GZ curve of test canoe by Hydromax ship stability software

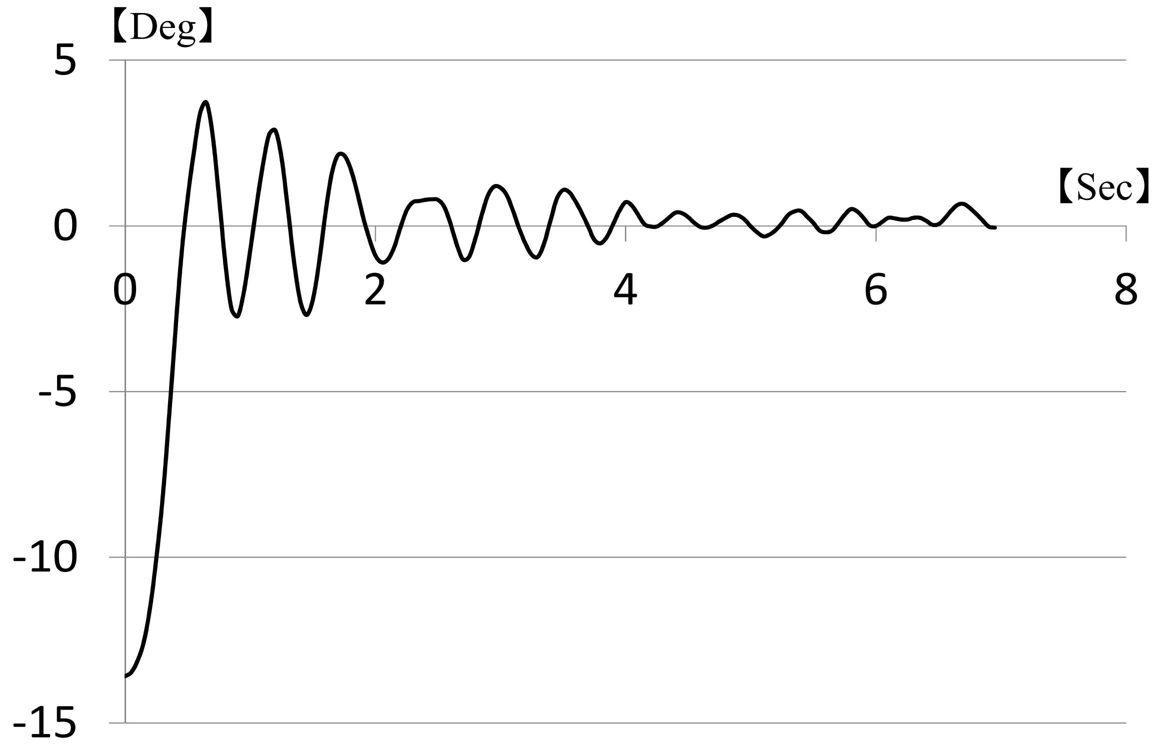

Fig. 3-10 Example of wave forms in Oscillation test

(nobody on board and outrigger distance are 1.3m)

Table 3. Result of Oscillation test by each condition

Condition	Nobody onboard			One person sit-down		
Outrigger Distance【m】	1.0	1.3	1.7	1.0	1.3	1.7
Rolling period【s】	0.70	0.67	0.82	0.98	0.83	0.73
N-Coefficient (Between θ_1- θ_2)	0.379	0.334	0.583	0.280	0.270	0.329

Fig. 3-11 State of working a Ro-scull in Outrigger canoe

CHAPTER 4

IMAGE ANALYSIS FOR WORKING A RO-SCULL OF INDONESIAN OUTRIGGER CANOE[40)]

4.1 Introduction

Japanese Wasen has a very slim hull and a main keel which is slightly curved upward near the bow. The hull is constructed with a very wide keel, narrow lower side plank, stem post and transom. The hull is square in the middle because the side planks are nearly upright. In Japan, the wooden small fishing boat called Wasen with a scull called Ro that was a human-powered propelling gear has been used since long time ago. Ro has almost disappeared due to the spread of the power engine of the outboard motor as well as a small fishing canoe hull form. In Addition, it has been progressed to the FRP boats due to shortage of material timber and getting older of Japanese Wasen boat builder[41-44)].

There are 4 traditional types of device to run the boat in Japan. Sao is long bamboo or wood to push the bottom of the shallow rivers, pond or lake. Uchikai is the same as the paddle of canoe. Kai, the same as the rowing oar. It is useful for short and fast rowing. Ro-scull is the hydrodynamic lift produced by the long blade propels the boat gently and effectively. It is useful for long time boating for 2 hours over, but not so fast. The mechanism of Ro is the blade gently sideways through the water. The sectional shape of the blade is just like the wing. It creates the hydrodynamic lift[45-46)]. It runs the boat very gently and economically.

In the chapter before, the stability has been checked. From the result, Indonesian outrigger canoe can be operated by Ro. In this chapter the writer compared operating of Ro scull between Japanese Wasen and Indonesian outrigger canoe from image analysis. The purpose of this study is to examine working a Ro-scull to outrigger canoe in order it can be applied to Indonesian canoe. This report deals with the result of stability by inclining test and oscillation test.

4.2 Methodology

4.2.1 Materials

The Ro-scull used for the experiment was size 10 (Length overall=4.7m), that was commonly used in Wasen. In order to reduce of weight and to enhance the maneuverability, the lower part of Ro-scull blade was cut off to make its length 4.2m. As shown in Fig.4-1, the weight of 1 kgf was fastened onto the tail edge of Ro-scull blade in order to make it stay in the water is easy. Six testee of sculler, who are sorted beforehand to three skill levels of veteran, middle class and beginner of working a Ro-scull according to the questionnaire survey, performed this experiment.

4.2.2 Analysis of the data

Image data was obtained by using a camera digital (Canon IXY 10S). It is available 30 frames per second and was fixed on the bow with tripod stand to record the motion of testee sculler's working a Ro-scull.

About 30 strokes of each testee sculler's motion of working a Ro-scull were shot. The recorded motion pictures were analyzed about the movement of six points including head, Rosaki (front edge of Ro-scull arms), right elbow, waist, right knee, and left knee as shown in Fig. 4-2 using of two dimensional video image analyzing software (DippMotion2D V.3.20KP). For the comparison with the experiment of working a Ro-scull of Wasen, six analysis points were determined. Position of Rogui (scull lock) was assumed as a base point, and the coordinate point of analysis points was calculated with the actually measured inner distance between the both sides of canoe at the stern as the calibration value. The movement volume of each analysis point was calculated from obtained data and compared to the veteran sculler's working a Ro-scull of Wasen, also the difference of how to work a Ro-scull between individual testee sculler's was measured.

4.3 Results and discussions

4.3.1 Improvement of canoe

Since canoe is not assumed to be propelled by a scull, it is difficult to work a Ro scull on a canoe for standing. Therefore, the following improvements as shown in Fig. 4-1 were made on the hull before the experiment. Rogui and Rodoko were mounted on the stern, shown in Fig. 4-3 and moreover, the floating structure was mounted on the stern to enhance the hull stability and buoyancy force. Similarly in order to enhance the hull stability and buoyancy force of outrigger with PVC pipe of diameter 10 cm. The length of outrigger was set to about 2.5 m by reference of previous report. This was determined to follow the ratio of outrigger length to hull length of canoe being used in Indonesia. The distance between two outriggers could be varied to three levels from minimum 110 cm to maximum 170 cm. The outrigger distance always set to maximum size of 170 cm in the experiment of this time. Actually, working a Ro-scull experiment was performed with consideration for the stability of improved canoe.

4.3.2 Comparison of the movement of working a Ro-scull

The sequence photograph of working a Ro-scull motion of three testee scullers with different scull and displays in order of veteran, middle class and beginner are given in Fig. 4-4. In working a Ro-scull, a sculler propels a boat by alternately repeating one motion of pushing a Ro-scull away from the body (pressing) and the other of pulling a Ro-scull to the body (reserving). Comparing to the veteran of the left, the middle class of the midst and the beginner of the right were standing with their backs bent.

Figure 4-5 shows the movements of respective points of each testee sculler through one stroke. In the figure, head and waist, waist and right elbow, right elbow and rosaki, waist and left knee then waist and right knee were respectively connected with a straight line. The figure demonstrates the movement of each point every 1/30 second. More specifically, the figure displayed the movement of testee scullers body from an anterior view every 1/30 second. The lines connecting Rosaki and right elbow are divided to thick part for every testee sculler. This shows the movement shifting from pressing to reserving and the one shifting adversely from reserving to pressing. Focusing on the line connecting waist and right knee and the line connecting waist and left knee, the former line of testee sculler B is out of the latter line of the left. This means the line connecting both knees opens with certain angle for centerline. Whereas as for testee sculler A and I, the line connecting waist and right knee and that connecting waist and left knee are almost parallel. This means that the line connecting both knees is on parallel with the centerline. It was found that A and I were standing with legs open in parallel with centerline. That is, testee sculler A and I were working a Ro-scull with their bodies whose right beside was facing the centerline. Testee sculler B was working a Ro-scull in stepping back with the right foot from the centerline or in other words slightly turning its body to the right. When working a Ro-scull, a hull repeats the rolling along with pressing and preserving. In that time, if a sculler stands with legs open in parallel with centerline, it becomes difficult to keep balance against rolling. Therefore, testee sculler A and I were standing with their backs bent. Meanwhile, testee sculler B was working a Ro-scull in well keeping balance by slightly turning its body to the right. Meanwhile, testee sculler B was working a Ro-scull in well keeping balance by slightly turning its body to the right. Focusing on the movement of head, the head of testee scullers B showed the largest movement among three testee scullers. This indicates that testee sculler B moved its head most largely to the canoe's side. Consequently, testee sculler B's motion to work a Ro-scull was bigger than other two testee scullers. As described in previous report, the large and slow stroke is suitable for the long distance than the faster pitch stroke. Accordingly, when working a Ro-scull for long distance to keep feet partway apart and to plant its feet firmly on a floor like testee sculler B is easy and lasts long comparing to testee sculler A and I.

4.3.3 Comparison of trajectory of Rosaki when working a Ro-scull

The trajectory of three testee culler's Rosaki and is the extraction of four cycles of working a Ro-scull motion as shown in Fig. 4-6[45)]. For reference, the trajectory of veteran sculler G in a past experiment conducted on Aba near Nagasaki city was displayed. The trajectory of testee sculler G is shifted upward vertical direction by one meter to make a comparison with this experiment easy. In comparison with the past experiment in Aba, the emotional range of the trajectory of Rosaki in this experiment has become smaller in the case of either testee sculler. This indicates that the motion of pressing and reserving was performed in a narrow range. It is believed that the Ro-scull of canoe could be handled in the range narrower than that of Wasen because of foot is unbalance while working a Ro-scull and then the narrow width of test canoe. In comparison by testee sculler, testee sculler B had a minimum moving range. Also B was working a Ro-scull in around the center of screen than other two testee scullers. Testee sculler A was working a Ro-scull in the farthest place from the center of screen. B was working a Ro-scull in the lowest position among three testee scullers. Contrary, A was working a Ro-scull in the highest position. If a sculler tries to greatly push away the blade of Ro-scull in order to increase the canoe speed, Rosaki has to be pushed outward when pressing. Comparing to a Wasen, a canoe sways widely from side to side. Also, in order to push Rosaki outward, a sculler has to work a Ro-scull with stretching Rosaki at a lower position in the context of the length of Hayao rope (a rope connecting a Ro-scull hull). However, if Rosaki is stretched at a lower position, the front edge of Ro-scull blade goes just under the water surface. Consequently, Ro-scull blade paddles trough the water near the surface and may not contribute to the propulsion force. Actually, when testee sculler A and I are working a Ro-scull, Ro-scull blade floats above the water surface. The Ireko (pivot of Ro-scull) often comes off Rodoko is shown in Fig. 4-2. Therefore, in order to work efficiently the Ro-scull of this canoe, it is necessary to maneuver of Ro-scull little by little near the centerline of the canoe.

Focusing on the trajectory of Rosaki, it almost traces out a figure of eight in Wasen. In the experiment of canoe although test sculler B slightly show such tendency, other two shows the shape close to the circular movement. Since the movement volume of Rosaki remains in a narrow range, this difference is not due to the difference of skill level.

4.4 Conclusions

Based on the previous report, the authors have examined the potential of transfer of the skill of working a Ro-scull to outrigger canoe. Originally, the Ro-scull has been used in a traditional Wasen. Therefore it is difficult to apply a Ro-scull directly to a canoe for standing up because of different hull form. The author made some improvements in the hull form so that it became able to work a Ro-scull in a canoe. It is intended to find the difference of veteran's way to work a Ro-scull and implementing the image analysis of such motions. It is investigating the difference in how to work a Ro-scull depending on the skill level of testee sculler from the comparison of several testee scullers whose skill levels were varied.

From the results and discussions above, the author wants to make some conclusion as follow:

(1) The motion of working a Ro-scull of canoe was smaller than of wasen because a sculler couldn't take a full motion with planting its feet firmly on the floor due to the narrow width of canoe.

(2) There was no clear difference of skill level among testee sculler because the range in which a Rosaki moved was narrow. However, from the view point of propulsion efficiency, the way to work a Ro-scull by keeping feet part way apart was regarded efficiency because of

sculler's posture became stable and the Ro-scull blade went deeps under the water due to stretching of Rosaki in lower position.

(3) It was deemed necessary to keep the distance of both feet at least similar to the width of shoulders in order to work a Ro-scull of canoe as well as working that of Wasen.

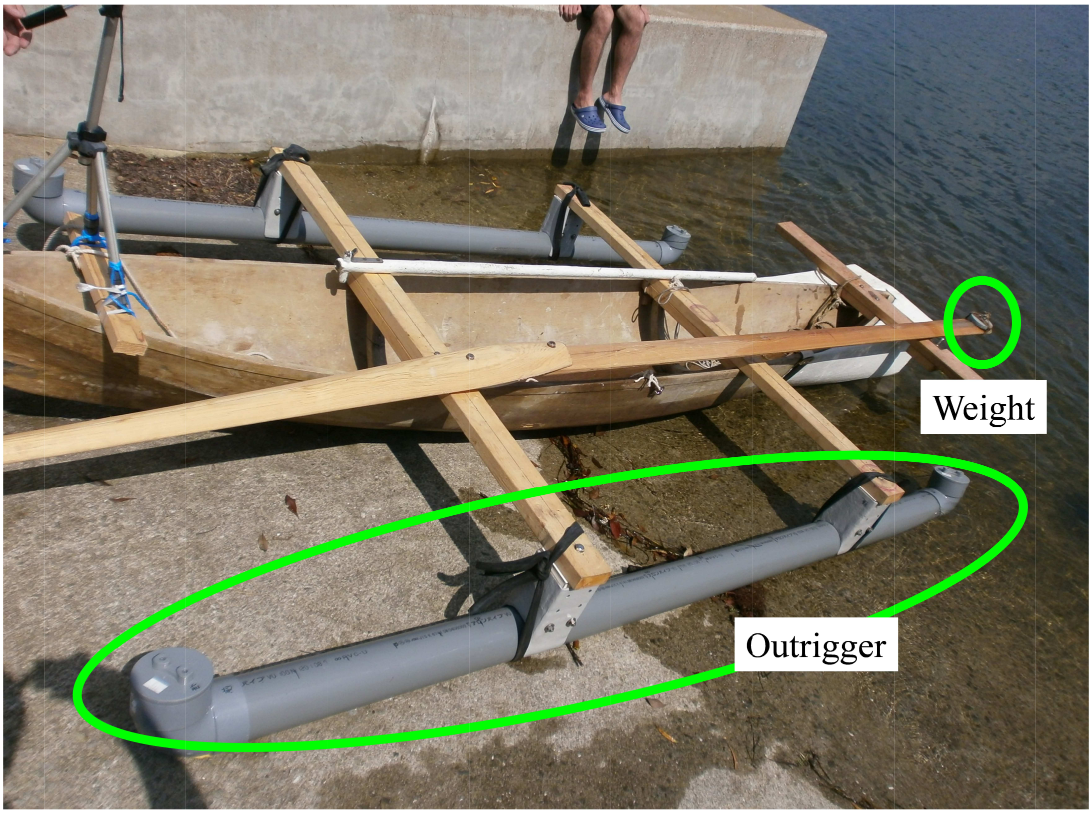

Fig. 4-1 Shape of outrigger canoe and Ro-scull

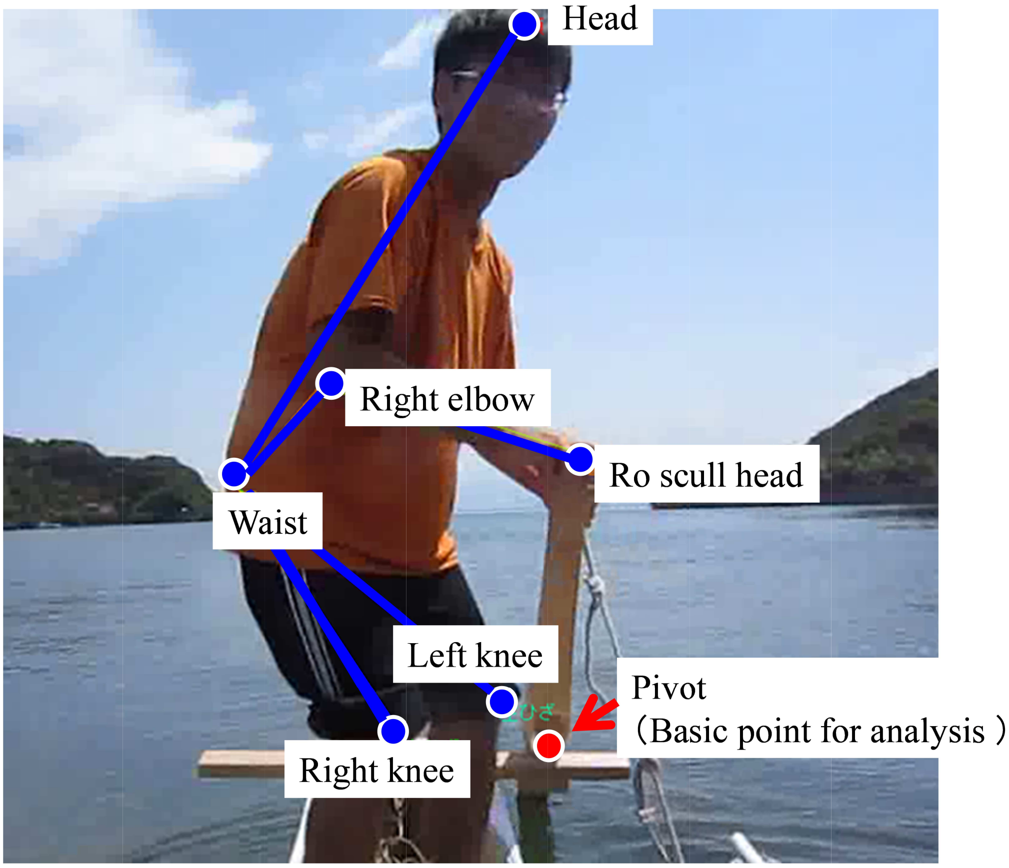

Fig. 4-2　Analysis points (six points)

Fig. 4-3 Setting of the Ro gui on the bed Rodoko

Testee B　　Testee A　　Testee I

Veteran　　Middle class　　Begineer

Fig. 4-4 Motion of working a Ro-scull for three tests

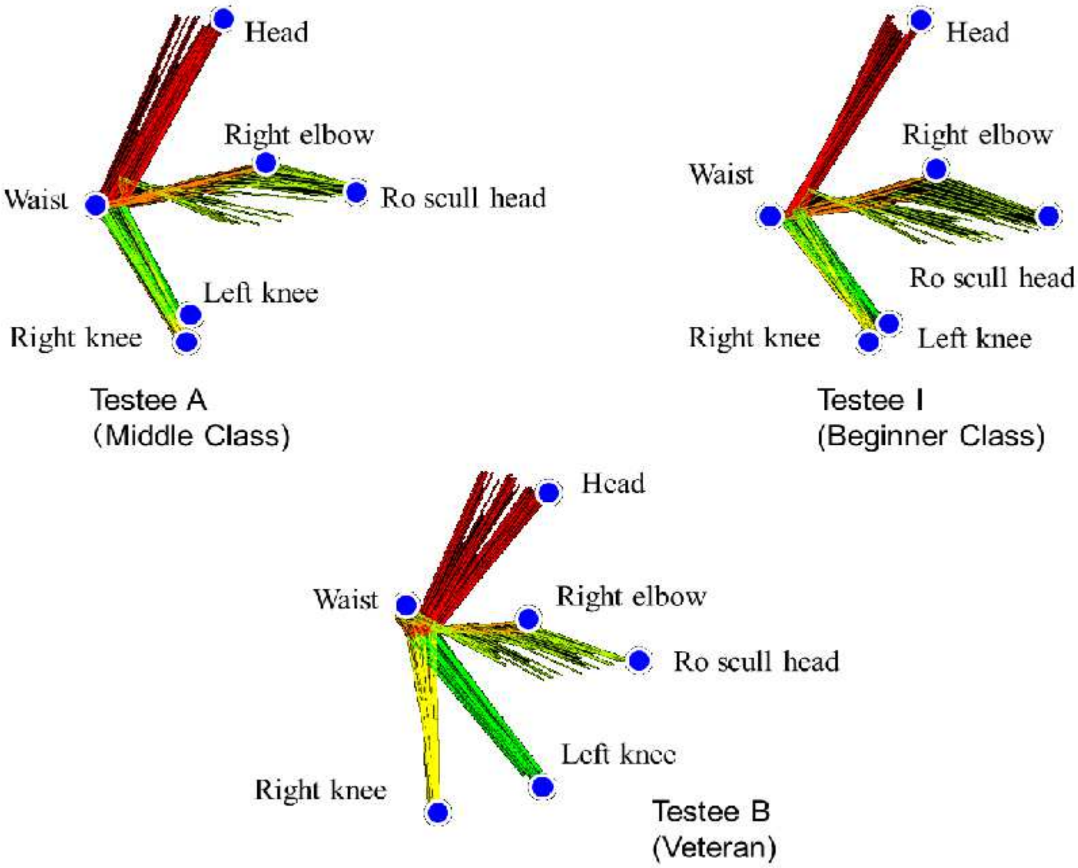

Fig. 4-5 Three tests motion of working a Ro-scull for one cycle

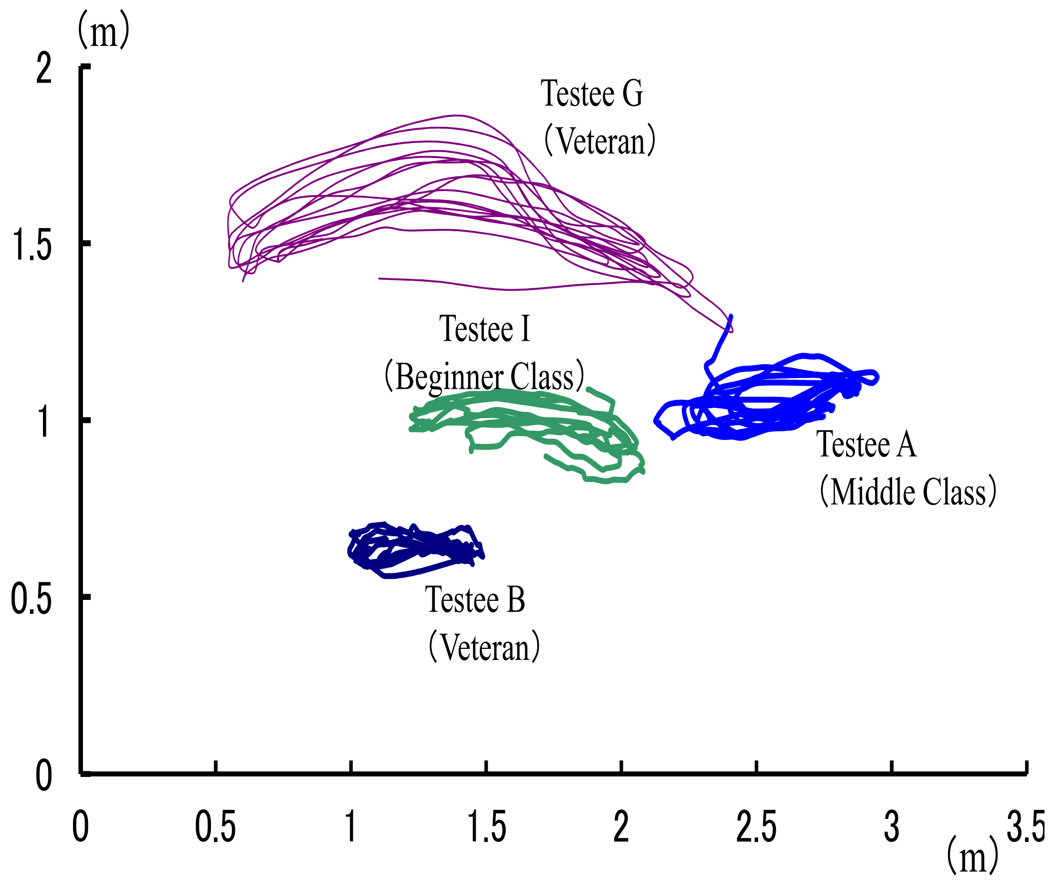

Fig. 4-6 Trajectories of the motion of blade apex of Ro-scull by testee[45)]

CHAPTER 5

GENERAL DISSCUSIONS

According to the statistical analysis of hull type and characteristics of Indonesian outrigger canoe and Japanese Wasen on this study, Indonesian outrigger canoe is very slim hull with small draft, which means low resistance and is propelled with paddle and sometimes sail. Indonesian outrigger canoe has one and double outriggers, that is, they have an outrigger on each side of the canoe. As outriggers moved into more open water, the single outrigger was structurally safer. The outrigger canoes in Sulawesi and Molluca Island have a hull with two sharp ends[47)]. The local varieties in hull-lines and outrigger framework are seen by fishing village. By comparison, the double outrigger stands a good chance of suspending the main hull from the outriggers in heavy seas. Londe and pelang are local name of outrigger canoe. Londe has edges are sharp, but pelang has edges are flat. In Indonesia, those fishing boats are also propelled mechanically. The typical of outrigger canoe is almost the same with the small fishing boat in Okinawa prefecture locally called Sabani. Sabani in Okinawa, a fishing boat has a unique construction originated from a dugout sabani (kuibuni) made from Japanese pine, cedar, deal, oaks or canfer tree. Briefly speaking, the sabani in nowadays are semi-dugout or planked boat which have hull shape of old dugout[48)].

In Japan, the traditional boat is known as the Wasen. Japanese small fishing boat is used to be propelled with a Ro-scull. The Ro-scull is a traditional propelling device for small boat using hydrodynamic lift force. The traditional Japanese boats are characterized by relatively thick planking and few, if any frames. Where frame are not used, hull are strengthened by athwart ship beams are connected to the hull with wedged mortise and tenons. Hull is hard chine with a wide plank keel supporting two garboard planks, with two nearly vertical planks completing the hull. Planking is usually Japanese cedar with cypress often being used for beams, stem and transom. However, the wooden Wasen has almost disappeared. The FRP boats are replacing wooden wasen, whereas they are partly inheriting hull form from Wasen.

Indonesian outrigger canoe used as fishing boats are separated into three groups that is angling, gillnet and seiner. Angling type has the smallest length and the width of outrigger distance BB. The minimum length among all types of boat was around 300 centimeters and BB/2 that was assumed to be 99 centimeters. On the other hand, a traditional Wasen boat has also 300 centimeters of length and 102 centimeters breadth at minimum. This means there is the possibility of applying a Ro-scull to the remaining type of canoes.

The statically stability of canoe was examined from the data of inclining test and oscillation test. These tests were conducted under the following condition depending on set outrigger by nobody on board inclining test and oscillation test), one person on board sitting down (inclining test and oscillation test) and on person on board standing up (inclining test only). GM (transverse metacentric height) values were calculated when the outrigger distance was arbitrarily varied. GM value with one person standing up was estimated to be around 1.0 meter in the case of 1.3 meters outrigger distance. Where the draft when lightly loaded and nobody on board was about 14 centimeters, the displacement became about 120 kgf that was almost equal to the weight at the actual experiment. In the case of the narrowest outrigger distance of 1 meter, GM value became about 1.5 meters. In the same distance, GM value obtained from inclining test was about 1.7 meters. GM value calculated by ship stability software was little smaller than that obtained from inclining test. Then it was found that working a Ro-scull was possible. In the oscillation test, the boat immediately become still after only one rolling and this means that N-coefficient seems to be very big and the result of rolling period in initial 3 times average is about 0.67 seconds. The first about rolling period, average rolling period is ranged between 0.7 to 1.0 second. The second, about N-coefficient between first rolling motion $\theta 1$ and $\theta 2$ of canoe is approximately ten times or more large than usual of ship. This means that the outrigger canoe can damp the rolling motion quickly.

The experiment of working a Ro-scull of Indonesian outrigger canoe was performed by veteran and non-veteran testee sculler. About 30 strokes of each sculler's motion were analyzed about the movement of six points including head, Rosaki (front edge of Ro-scull), right elbow, waist, night knee, and left knee in using the two dimensional video image analyzing software (DippMotion2Dv.3.20KP). In working a Ro-scull, a sculler propels a boat by alternately repeating one motion of pushing a Ro-scull away from the body (pressing) and the other of pulling a Ro-scull to the body (reserving). The veteran was working a Ro-scull in stepping back with the right foot from the centerline and it seemed to be simple and could operate long time, however non-veterans were standing with legs open in parallel with centerline and it was difficult to keep balance against canoe's rolling.

Based on this study, the author made a comprehensive consideration of the working a Ro-scull experiments to find out a possibility to transfer the Ro-scull of Japanese Wasen and the skills of working it to Indonesian outrigger canoe. Consequently, it was revealed there was room for further improvements to transfer the Ro-scull and skills of working to Indonesian outrigger canoe. However, the video footage that recorded the working a Ro-scull motions and analyzed became an optimum learning tool to imagine the way of working a Ro-scull when testee scullers who looked a Ro-scull first time to learn working a Ro-scull. In addition, the oscillation test showed a canoe had a characteristic than an oscillation was settled immediately. It was difficult to work a Ro-scull of canoe as well as Wasen in rough waters. From this study, it can be recommended that working a Ro-scull for the Indonesian outrigger canoe, like Japanese Wasen, is more suitable when conducted in the calm surface such as coastal waters and inland waters including lakes and rivers that are numerous in Indonesia.

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NOMENCLATURE

Loa	: Length over all
Lpp	: Length between perpendicular
B	: Moulded breadth
D	: Moulded depth
d	: Draft
Lf	: Length of outrigger float
BB	: Transverse distance amidship from an outrigger to another one (double rigger) or opposite side of the hull (single rigger)
Intv	: Longitudinal interval distance between fore and after outrigger booms
Hs	: Height of stem top
Hn	: Height of stern top
Hdo	: Height of dugout base
El	: Snout's length of the canoe
n	: Data number
W	: Displacement
GM	: Metacentric height
GZ	: Righting arm
Tr	: Rolling period

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